CHAPTER 4

STANDARD HVAC CONTROL SYSTEMS

1. GENERAL.

a. The complete HVAC control system design will include a series of drawings for each HVAC control system, based on the standard control systems presented in this chapter.

b. Variations to these control systems are shown in chapter 5.

c. Air delivery systems can be designed with or without return fans. For example, selected systems are shown with return fans. These HVAC systems are the multizone system, the bypass multizone system, the dual-duct system, and the VAV system.

d. Where required, the control of a return fan can be incorporated into any air delivery HVAC system shown in this manual by appropriately modifying the HVAC control system drawings.

e. The decision to use only a supply fan for HVAC systems versus the use of both a supply and a return fan is based on the following: lower first cost, lower maintenance cost, lower energy costs, and less complex control systems. The advantages of the supply / return fan system include positive control of the outside air, return air, and relief air quantities under varying modes of operation. Return fans are sized smaller than the supply fan by the amount of air necessary for minimum outside air, space pressurization air, and exhaust makeup air.

f. In the case of the VAV system, the control loop necessary to allow the return air flow to vary as the supply air flow changes is known as the return fan volume control loop. This loop is costly, complex, and, in some applications, difficult to control with stability. A return fan should be used in a VAV system only when absolutely necessary. The need for a return fan can be reduced by keeping return duct losses to a minimum using a plenum or making the return duct as short and as large as possible.

g. The transmitter ranges shown are standard. These ranges match corresponding EMCS ranges where appropriate, and will not be changed.

h. The setpoints, timeclock schedules, etc. used throughout this chapter are used for example purposes only. The actual values to be used in contract documents must be determined by the designer as appropriate for each project and location.

2. IDENTIFICATION OF CONTROL SYSTEM DEVICES.

Control system devices will be numbered in accordance with the convention described for the unique identifiers shown in Section II of the Glossary.

3. PROJECT SPECIFIC DRAWINGS.

To make the standard HVAC control system drawings project specific:

a. Add or delete loops as required.

b. Use a common time clock and common control panel where appropriate for HVAC systems (as described in chapter 5) unless the HVAC system is extended to EMCS.

c. If the project has EMCS, the time clock may be deleted and replaced with EMCS contacts.

d. Incorporate system variations as required.

e. Replace "XX" in the drawing titles and unique identifiers with numbers specific to the project HVAC control system.

f. For single-loop controller applications, modify HVAC control panel interior door layouts, back panel layouts, and terminal block layouts as required. For DDC applications, modify data terminal strip layouts as required.

g. Parameters shown in the equipment list must be modified to make the standard HVAC control system drawings project specific.

h. Damper and valve position diagrams.

4. SPACE TEMPERATURE CONTROLLED PERIMETER RADIATION CONTROL SYSTEM.

a. Description of perimeter radiation system. This system consists of fin-tube radiation, a portion of the hydronic heating system. Figure 4-1 shows the schematic and ladder diagrams and the equipment schedule for this type of system.

Figure 4-1. Space temperature controlled perimeter radiation control system.

b. General sequence of operation. A room thermostat controls a perimeter radiation valve to maintain a set temperature. The following options are available:

(1) Two-position thermostat with two-position valve.

(2) Microprocessor-based thermostat which cycles a two-position valve during the occupied mode to maintain the programmed occupied mode setpoint, and during the unoccupied mode to maintain the programmed unoccupied mode setpoint.

(3) A modulating thermostat with a modulating valve.

c. Detailed sequence of operation.

(1) In two-position control, the contacts of room thermostat T-XX01 close on a rise in temperature to its setpoint, energizing normally-open valve VLV-XX01, which closes. On a fall in temperature below its setpoint, the contacts of thermostat T-XX01 open, de-energizing valve VLV-XX01, which opens.

(2) In modulating control, thermostat T-XX01 modulates valve VLV-XX01 to maintain its setpoint.

5. UNIT HEATER TEMPERATURE CONTROL SYSTEM.

a. Description of unit heater system. This system consists of a unit with a heating coil and a fan to circulate air through a coil to provide heat to the space served. The heating coil is uncontrolled (no valve), but the fan is controlled. Unit heaters are used to provide heat in mechanical spaces and stairwells. Figure 4-2 includes the ladder diagram and equipment schedule for this type of system.

Figure 4-2 Unit heater temperature control system.

b. General sequence of operation. A unit thermostat cycles the unit heater fan to maintain its setpoint temperature. A microprocessor-based thermostat could also be used to provide for a night-setback setpoint, as shown in chapter 5.

c. Detailed sequence of operation. Space thermostat TSL-XX01 has a manual "OFF-AUTO" switch. When the switch is indexed to "OFF", the unit-heater motor is de-energized. When the switch is indexed to "AUTO", the fan starts when the space temperature falls below the thermostat setpoint, and stops when the temperature rises to its setpoint.

6. GAS-FIRED INFRARED HEATER CONTROL SYSTEM.

a. Description of infrared heater system. This system consists of gas infrared heaters. Figure 4-3 shows the ladder diagram and equipment schedule for this system.

Figure 4-3. Gas-fired infrared heater temperature control system.

b. General sequence of operation. A thermostat cycles the infrared heater (or heaters) to maintain the programmed setpoint.

c. Detailed sequence of operation. A microprocessor-based room thermostat TuP-XX01 has an "AUTO-OFF" switch. When the thermostat switch is indexed to the "OFF" position, the infrared heater remains off. When the switch is indexed to the "AUTO" position, the infrared heater cycles during the occupied mode to maintain the programmed occupied temperature setpoint and during the unoccupied mode to maintain the programmed unoccupied temperature setpoint.

7. SMALL PACKAGED UNITARY SYSTEM CONTROL SYSTEM.

a. Description of all-air small packaged unitary system. This system consists of a small self-contained air handling unit provided with both heating and cooling equipment. Figure 4-4 shows the ladder diagram and equipment schedule for this system.

Figure 4-4. Small packaged unitary system control system.

b. General sequence of operation. When indexed to "HEAT", a microprocessor-based room thermostat cycles the unit fan and heating equipment, to maintain the programmed temperature. When indexed to "COOL", the thermostat cycles the fan and cooling equipment, to maintain the programmed temperature.

c. Detailed sequence of operation. Microprocessor-based room thermostat TuP-XX01 is equipped with "HEAT-OFF-COOL" and "AUTO-ON" switches. It can be programmed to maintain separate occupied and unoccupied heating mode and occupied cooling mode temperatures. When the system switches are indexed to "HEAT" and "AUTO", the thermostat cycles the heating unit and the fan to maintain the programmed temperature; the cooling unit remains de-energized. When the thermostat is indexed to "COOL" and "AUTO", the thermostat cycles the cooling unit and the fan to maintain the programmed temperature; the heating unit remains de-energized. At the conclusion of the cooling occupied mode, the system is de-energized and remains de-energized throughout the unoccupied mode. When indexed to "ON" the unit fan runs continuously. When the "HEAT-OFF-COOL" switch is indexed to "OFF", neither heating nor cooling can be energized.

8. DUAL-TEMPERATURE FAN COIL UNIT CONTROL SYSTEM.

a. Description of dual-temperature fan coil system. The system consists of a fan and a dual-temperature coil that is supplied with cold water during the cooling season and hot water during the heating season. Figure 4-5 shows the schematic and ladder diagrams and equipment schedule for this type of system.

Figure 4-5. Dual-temperature fan coil unit temperature control system.

b. General sequence of operation. A wall-mounted two-stage thermostat cycles the fan in winter to maintain its lower setpoint and in summer to maintain its higher setpoint. Fan speed is manually indexed by the room occupants.

c. Detailed sequence of operation.

(1) Wall-mounted two-stage thermostat TS-XX01 has two setpoints. The lower setpoint is a heating mode setpoint, which, on a fall in temperature, cycles the fan to maintain the setpoint. The higher setpoint is a cooling mode setpoint, which, on a rise in temperature, cycles the fan to maintain the setpoint.

(2) Strap-on aquastat TS-XX02, located on the return line downstream of the fan coil 3-way valve, senses whether hot water or cold water is being supplied to the dual-temperature coil, and its snap-acting contacts determine which thermostat contact and setpoint will cycle the fan.

(3) Whenever the fan is energized, a three-way electric valve VLV-XX01 is also energized, to open the hydronic medium to the coil. Whenever the fan is de-energized, VLV-XX01 is also de-energized and closes the hydronic medium to the coil and opens it to coil bypass.

9. CONTROL SYSTEMS THAT REQUIRE SINGLE-LOOP CONTROLLER PANELS.

a. An HVAC control panel is required for each system that requires the control capabilities of the single-loop controller. The designer will show all the details of the standard HVAC control panel on the contract drawings. These details will describe the construction, mounting, and general arrangement of the standard HVAC control panel.

b. In addition, the contract drawings for each control system will show the specific interior door arrangement, showing front and rear views, the back panel layout, and the terminal block layout for the control system, on the contract drawings.

10. STANDARD SINGLE-LOOP CONTROLLER HVAC CONTROL PANEL.

a. Figures 4-6a through 4-6i will provide the guidance for the HVAC control panel arrangement for typical HVAC control systems.

Figure 4-6a. Standard wall-mounted HVAC control panel arrangement.

Figure 4-6b. Section "A-A" through the standard HVAC control panel.

Figure 4-6c. Standard HVAC control panel interior door.

Figure 4-6d. Standard HVAC control panel back panel layout.

Figure 4-6e. Standard HVAC control panel terminal block assignments.

Figure 4-6f. Controller wiring.

Figure 4-6g. Supply fan and return fan starter wiring.

Figure 4-6h. Exhaust fan and pump starter wiring.

Figure 4-6i. HVAC control panel power wiring.

b. The standard wall-mounted HVAC control panel (see figure 4-6a) is a standard enclosure of a specific size. This panel contains the single-loop controllers, IPs, power supply, indicators, gauges, function modules, relays, clocks, and terminal blocks, for connection to external devices and circuits and for connection to EMCS.

c. Figure 4-6b, section "A-A" through the panel, shows the general arrangement of the inside of the panel. The interior door, located behind the exterior key-locked door, is the mounting surface for controllers, receiver gauges, main air gauge, switches, and lights. The interior door has a continuous piano-type hinge to support the door and its devices. The back panel accommodates vertical and horizontal wiring ducts, and standard-size mounting rails. The mounting rails for the terminal blocks are elevated from the back panel to accommodate the wiring from the wiring ducts.

d. Figure 4-6c shows the general layout of the interior door for HVAC control panels. The front view shows that the panel's interior door will accommodate up to six controllers with receiver gauges in two rows of three controllers each. The main air gauge is on the right, and five pneumatic output indicators for IPs are located to the left of the main air gauge. The rear view shows rail-mounted IPs, connections to gauges, and a valve to access the main air for maintenance. In the event that additional space is required for function modules, such as loop drivers, they may be shown on this rail. The general arrangement shown will not be changed for the sake of symmetry. It is intended that this panel will accommodate one control system for an air-delivery HVAC system and may also accommodate hydronic or other HVAC control systems. The switch and pilot light matrix will have the devices arranged in the array shown.

e. Figure 4-6d shows the general arrangement of the back panel, which will have two vertical wiring ducts and four horizontal wiring ducts, with covers as shown. The mounting rail shown at the top of the panel will accommodate up to 15 relay bases, which will accept the wiring for plug-in relays. The relays will be placed from right to left in the numerical order of their unique identifiers. Below the relay mounting rail will be a horizontal wiring duct, and below this duct there will be three mounting rails and wiring ducts that will accommodate the terminal blocks to accept the control system wiring. There will be a mounting rail for function modules, time clock, and power supply located below the terminal block mounting rails and wiring ducts; loop drivers may also be mounted on this rail. A duplex receptacle, intended for maintenance use, will be mounted on the right side of the cabinet. The power conditioner and system fuses will be mounted on the left side of the cabinet. The system's dc power supply will be located to the left of the clock. The ac wiring will enter the wiring duct on the lower left of the panel and will be distributed vertically. The dc wiring will enter the wiring duct on the right and will also be distributed vertically.

f. The relative location assignments for three rows of numbered terminal block locations are shown in figure 4-6e. Only the terminal blocks needed for the specific control system loops will be included in the panel. Locations 1 through 70 in row 1 are dedicated to controller loop wiring in groups of 10.

g. Figure 4-6f shows the standard wiring for a typical controller and for a controller used as an economizer controller. The left side of the figure shows that terminal 1 is always a shield terminal, and that terminals 2 and 3 are always for the transmitter connection. These terminals are designated as PV. Terminal 2 is connected to a dc-power terminal block and is jumpered to terminal 4 to supply power to the CPA; terminals 4 and 5 make the CPA available to EMCS. The signal returns of PV and CPA are connected to a dc-power terminal. Terminals 6 and 7 are wired to PVR and allow the 4-20 ma PVR signal to be connected to EMCS. Terminals 8 and 9 are wired to OUT. Removal of the jumper connecting terminals 8 and 9 will allow the controller to interface with an electric actuator rather than an IP. The controller, TC, powers its output loop. Terminal 10 is an additional shield terminal. The right side of the figure shows that when the controller is used as an economizer controller, terminals 2 and 3 are connected to the return air temperature transmitter, and terminals 6 and 7 are connected to the outside air temperature transmitter. Terminals 8 and 9 contain the jumper for EMCS interface to the economizer logic.

h. Figure 4-6g shows the standard wiring for the HVAC system's supply fan and return fan starters. The "ENABLE-OFF" switch is connected to the supply fan only. If there are no smoke dampers, a jumper will be installed between terminals 185 and 186. 100-percent outside air systems with high-pressure fans will have end switches on the outside air damper to insure that the damper is open before the fan starts. 100-percent outside air units with electric actuators will have end switches on the outside air damper because of the inherently slower speed of the electric actuators in opening the damper. Under normal conditions, local control switches for the supply fan, return fan, and exhaust fan starters will be in the "AUTO" position. When the "ENABLE-OFF" switch is indexed to the "OFF" position, the return and exhaust fans will stop when the supply fan stops, through interlocked relay contacts in the "AUTO" position of the local starter control switch.

i. Figure 4-6h shows the wiring of exhaust fans when interlocked to other fans and also shows the wiring of pumps. The left side of the figure shows the exhaust fan wiring. This wiring is similar to the return fan wiring, except that a jumper is shown installed between terminals 205 and 206 because exhaust fans do not normally require the circuitry to prove that the exhaust dampers are open before the fan starts. If high-pressure fans are used for exhaust fans, the exhaust dampers should have end switches and should be wired as a return fan, as shown in figure 4-6g. The right side of the figure shows the pump starter wiring. A safety shutdown circuit is not required. A jumper is shown installed between terminals 205 and 206. Each pump will have an "ENABLE-OFF" switch.

j. Figure 4-6i shows the HVAC control panel power wiring for ac and dc sources.

11. CENTRAL PLANT STEAM HYDRONIC HEATING CONTROL SYSTEM.

a. Description of hydronic heating system. This hydronic heating system consists of a steam to hot water converter that provides hot water to a primary pumping system. The primary pumping system supplies hot water to secondary pumping systems that provide hot water to separate zones of space temperature control. Figures 4-7a through 4-7f show the system design for this type of heating system using a SLDC control panel. Figures 4-7g through 4-7j show the system design for this type of heating system using DDC controls.

Figure 4-7a. Control system schematic for central plant steam hydronic system.

Figure 4-7b. Control system ladder diagram for central plant steam hydronic system.

Figure 4-7c. Control system equipment for central plant steam hydronic system.

Figure 4-7d. Control panel interior door layout for central plant steam hydronic system.

Figure 4-7e. Control panel back panel layout for central plant steam hydronic system.

Figure 4-7f. Control panel terminal block layout for central plant steam hydronic system.

Figure 4-7g. DDC control system schematic for central plant steam hydronic system.

Figure 4-7h. DDC control system ladder diagram for central plant steam hydronic system.

Figure 4-7i. DDC control system equipment for central plant steam hydronic system.

Figure 4-7j. DDC control system I/O table and data terminal strip layout for central plant steam hydronic system.

b. General sequence of operation.

(1) The primary pumping system and the steam/hot water converter operate continuously whenever the outside air temperature is low enough for the building to require heating. When this occurs, an outside air temperature controller starts the primary pump, enables the converter control

system, and enables the secondary pumps to operate. The outside air temperature controller raises the primary hot water supply temperature as the outside air temperature falls.

(2) The primary hot water supply temperature controller maintains its setpoint by modulating the converter steam valve to maintain the scheduled primary hot water supply temperature.

(3) During the occupied mode, the secondary hot water pumps run whenever the primary hot water pump runs. Each zone temperature controller modulates its zone control valve to blend primary hot water supply with secondary hot water return in order to maintain the zone's space temperature setpoint, which is adjustable by the zone occupant.

(4) During the unoccupied mode, the secondary hot water pumps are cycled by the zone night thermostat to maintain the low limit setpoint and to prevent freezing. During this mode, the space temperature controller setpoint is determined by an adjustment within the system's HVAC control panel.

c. Detailed sequence of operation.

(1) Outside air temperature transmitter TT-XX-01 signals outdoor air temperature to temperature controller TC-XX-01. On a fall in outside air temperature to 16 degrees C (60 degrees F), the process variable (PV) contacts of TC-XX-01 close to energize relays R-XX-04 and R-XX-05, and pilot light PL-XX-02. The contacts of relay R-XX-04 energize the primary hot water pump, and the contacts of relay R-XX-05 enable the secondary pumps. The auxiliary contacts of the primary pump starter energize relay R-XX-06, whose contacts then allow the primary water temperature control system to operate.

(2) On a rise in outside air temperature to 17 degrees C (62 degrees F), the PV contacts of controller TC-XX-01 open to de-energize relay R-XX-04 to stop the primary pump, and to de-energize relay R-XX-05 to stop each secondary pump. The auxiliary contacts of the primary pump starter open, de-energizing relay R-XX-06, whose contacts then remove valve VLV-XX-01 from control, causing it to close.

(3) Controller TC-XX-01 raises the setpoint of primary hot water supply temperature controller TC-XX-02 as the outside air temperature falls, and lowers the setpoint as the outside air temperature rises.

(4) Temperature transmitter TT-XX-02 signals the primary hot water supply temperature to temperature controller TC-XX-02, which then maintains its setpoint by varying its signal to current-to-pneumatic transducer IP-XX-01. The pneumatic signal from IP-XX-01 modulates converter steam valve VLV-XX-01 to maintain the primary supply water temperature setpoint of controller TC-XX-02.

(5) Temperature transmitter TT-XX-03 signals the zone space temperature to controller TC-XX-03, which then maintains its setpoint by varying its current output signal to transducer IP-XX-02. The pneumatic signal from IP-XX-02 modulates secondary zone control valve VLV-XX-02. Zone control valve VLV-XX-02 mixes primary supply water with secondary return water to maintain the zone space temperature setpoint. The temperature control loops for the other secondary zones function identically.

(6) Throughout the occupied mode, the contacts of time clock CLK-XX-01 are closed to energize relays R-XX-01, R-XX-02, and R-XX-03, and to turn on pilot light PL-XX-01. The contacts of relay R-XX-01 connect temperature setpoint device TSP-XX-01 to allow manual adjustment of the setpoint of temperature controller TC-XX-03. Relay R-XX-02 provides the same function for TSP-XX-03 in

adjustment of controller TC-XX-04. Relay R-XX-03 closes contacts in the starter control circuits of the secondary pumps. The secondary system pumps will start whenever the contacts of relay R-XX-03 (occupied) and R-XX-05 (heating) are closed in their respective pump starter circuits.

(7) During the unoccupied mode, the contacts of time clock CLK-XX-01 are open and de-energize relays R-XX-01, R-XX-02, and R-XX-03; pilot light PL-XX-01 turns off. The transfer of contacts of relay R-XX-01 transfers the temperature setpoint adjustment of TC-XX-03 from TSP-XX-01 to TSP-XX-02; likewise, relay R-XX-02 transfers the temperature setpoint adjustment of TC-XX-04 from TSP-XX-03 to TSP-XX-04. The contacts of relay R-XX-03 open the secondary pump starter circuits, to place the secondary pumps under the respective night thermostats TSL-XX-01 and TSL-XX-02. When the zone space temperature falls to 13 degrees C (55 degrees F), the zone's secondary pump is energized and remains energized until the temperature rises to 14 degrees C (57 degrees F).

d. Sequence of operation for DDC applications.

(1) The DDC system shall accept a signal from a sunshielded outside air temperature sensing element and transmitter located as shown. The DDC system shall start and stop the pumps at the outside air temperature shown. The DDC system shall reset the hydronic heating supply temperature setpoint in a linear schedule based on the outside air temperature as shown. The DDC system shall accept a signal from a temperature sensing element and transmitter located in the hydronic heating supply line and the DDC system output shall modulate the converter steam control valve to maintain the reset schedule setpoint in the hydronic heating supply line.

(2) When the system time schedule places the system in the occupied mode, a space temperature sensing element and transmitter located as shown shall signal the DDC system, which shall maintain the space temperature setpoint by modulating the secondary hydronic system zone valve.

(3) When the system is in the unoccupied mode, the space temperature setpoint shall be as shown.

12. SINGLE BUILDING HYDRONIC HEATING WITH HOT WATER BOILER CONTROL SYSTEM.

a. Description of the hydronic heating system. This hydronic heating system consists of a hot water boiler that provides hot water to a primary pumping system. The primary pumping system supplies hot water to secondary pumping systems that provide hot water to separate zones of space temperature control. This control system varies the hot water flow through the boiler. Therefore, it can be used only with boilers whose operation is not affected by flow variation. A variation of this system which utilizes constant flow through the boiler is depicted in Chapter 5. Figures 4-8a through 4-8f show the system design for this type of heating system using a SLDC control panel. Figures 4-8g through 4-8j show the system design for this type of heating system using DDC controls.

Figure 4-8a. Control system schematic for single building hydronic heating system with hot water boiler.

Figure 4-8b. Control system ladder diagram for single building hydronic heating system with hot water boiler.

Figure 4-8c. Control system equipment for single building hydronic heating system with hot water boiler.

Figure 4-8d. Control panel interior door layout for single building hydronic heating system with hot water boiler.

Figure 4-8e. Control panel back panel layout for single building hydronic heating system with hot water boiler.

Figure 4-8f. Control panel terminal block layout for single building hydronic heating system with hot water boiler.

Figure 4-8g. DDC control system schematic for single building hydronic heating system with hot water boiler.

Figure 4-8h. DDC control system ladder diagram for single building hydronic heating system with hot water boiler.

Figure 4-8i. DDC control system equipment for single building hydronic heating system with hot water boiler.

Figure 4-8j. DDC control system I/O table and data terminal strip layout for single building hydronic heating system with hot water boiler.

b. General Sequence of Operation.

(1) The primary pumping system and the boiler operate continuously whenever the outside air temperature is low enough for the building to require heating. When this occurs, an outside air temperature controller starts the primary pump, enables the boiler to function under its own control system to maintain a constant boiler water temperature, and enables the secondary pump to operate. The outside air temperature controller raises the primary hot water supply temperature as the outside air temperature falls.

(2) The primary hot water supply temperature controller maintains its setpoint by modulating a valve to mix hot water from the boiler with return water from the primary pumping system to maintain the scheduled primary hot water supply temperature.

(3) During the occupied mode, the secondary hot water pumps run whenever the primary hot water pumps run. Each zone temperature controller modulates its zone control valve to blend primary hot water supply with secondary hot water return in order to maintain the zone's space temperature setpoint, which is adjustable by the zone occupant.

(4) During the unoccupied mode, the secondary hot water pumps are cycled by the zone's night thermostat to maintain the low limit setpoint and to prevent freezing. During this mode, the controller setpoint is determined by an adjustment within the system's HVAC control panel.

c. Detailed sequence of operation.

(1) Outside air temperature transmitter TT-XX-01 signals outdoor air temperature to temperature controller TC-XX-01. On a fall in outside air temperature to 16 degrees C (60 degrees F), the process variable (PV) contacts of TC-XX-01 close to energize relays R-XX-04, R-XX-05, and R-XX-06 and pilot light PL-XX-02. The contacts of relay R-XX-04 energize the primary hot water pump, the contacts of relay R-XX-05 enable the secondary pumps, and the contacts of relay R-XX-06 enable the boiler control circuit.

(2) On a rise in outside air temperature to 17 degrees C (62 degrees F), the PV contacts of controller TC-XX-01 open to de-energize relays R-XX-04 to stop the primary pump, to de-energize relay R-XX-05 to stop both secondary pumps, and to de-energize relay R-XX-06 to disable the boiler control circuit and to turn off pilot light PL-XX-02.

(3) Controller TC-XX-01 raises the setpoint of primary hot water supply temperature controller TC-XX-02 as the outside air temperature falls, and lowers the setpoint as the outside air temperature rises.

(4) Temperature transmitter TT-XX-02 signals the primary hot water supply temperature to temperature controller TC-XX-02, which then maintains its setpoint by varying its signal to current-to-pneumatic transducer IP-XX-01. The pneumatic signal from IP-XX-01 modulates primary hot water valve VLV-XX-01 to mix boiler water and primary return water to maintain the primary supply water temperature setpoint of controller TC-XX-02.

(5) Temperature transmitter TT-XX-03 signals the zone space temperature to controller TC-XX-03, which then maintains its setpoint by varying its current output signal to transducer IP-XX-02. The pneumatic signal from IP-XX-02 modulates secondary zone control valve VLV-XX-02. Zone control valve VLV-XX-02 mixes primary supply water with secondary return water to maintain the zone space temperature setpoint. The temperature control loop for the other secondary zone functions identically.

(6) Throughout the occupied mode, the contacts of time clock CLK-XX-01 are closed to energize relays R-XX-01, R-XX-02, and R-XX-03, and to turn on pilot light PL-XX-01. The contacts of relay R-XX-01 connect temperature setpoint device TSP-XX-01 to allow manual adjustment of the setpoint of temperature controller TC-XX-03. Relay R-XX-02 provides the same function for TSP-XX-03 in adjustment of controller TC-XX-04. Relay R-XX-03 closes contacts in the starter control circuits of the secondary pumps. The secondary system pumps will start whenever the contacts of relay R-XX-03 (occupied) and R-XX-05 (heating) are closed in their respective pump starter circuits.

(7) During the unoccupied mode, the contacts of time clock CLK-XX-01 are open, de-energizing relays R-XX-01, R-XX-02, and R-XX-03, and pilot light PL-XX-01 turns off. The transfer of the contacts of relay R-XX-01 transfer temperature setpoint adjustment of TC-XX-03 from TSP-XX-01 to TSP-XX-02; likewise, relay R-XX-02 transfers temperature setpoint adjustment of TC-XX-04 from TSP-XX-03 to TSP-XX-04. The contacts of relay R-XX-03 open the secondary pump starter circuits to place the secondary pumps under the respective night thermostats TSL-XX-01 and TSL-XX-02. When the zone space temperature falls to 13 degrees C (55 degrees F), the zone's secondary pump is energized and remains energized until the temperature rises to 14 degrees C (57 degrees F).

d. Sequence of operation for DDC applications.

(1) The DDC system shall accept a signal from a sunshielded outside air temperature sensing

element and transmitter located as shown. The DDC system shall start and stop the distribution pumps, boiler pump, and boiler at the outside air temperatures shown. The DDC system shall reset the hydronic heating supply temperature setpoint in a linear schedule based on the outside air temperature as shown. The DDC system shall accept a signal from a temperature sensing element and transmitter located in the hydronic heating supply line and the DDC system output shall modulate the hydronic heating system control valve to maintain the reset schedule setpoint in the hydronic heating supply line.

(2) When the system time schedule places the system in the occupied mode, a space temperature sensing element and transmitter located as shown shall signal the DDC system, which shall maintain the space temperature setpoint shown by modulating the secondary hydronic system zone valve.

(3) When the system is in the unoccupied mode, the space temperature setpoint shall be as shown.

13. CENTRAL PLANT HIGH TEMPERATURE HOT WATER HYDRONIC HEATING CONTROL SYSTEM.

a. Description of the hydronic heating system. This hydronic heating system consists of a high-temperature hot water converter that provides hot water to a primary pumping system. The primary pumping system supplies hot water to secondary pumping systems that provide hot water to separate zones of space temperature control. Figures 4-9a through 4-9f show the system design for this type of heating system using a SLDC control panel. Figures 4-9g through 4-9j show the system design for this type of heating system using DDC controls.

Figure 4-9a. Control system schematic for central plant high-temperature hot water hydronic heating system.

Figure 4-9b. Control system ladder diagram for central plant high-temperature hot water hydronic heating system.

Figure 4-9c. Control system equipment for central plant high-temperature hot water hydronic heating system.

Figure 4-9d. Control panel interior door layout for central plant high-temperature hot water hydronic heating system.

Figure 4-9e. Control panel back panel layout for central plant high-temperature hot water hydronic heating system.

Figure 4-9f. Control panel terminal block layout for central plant high-temperature hot water hydronic heating system.

Figure 4-9g. DDC control system schematic for central plant high-temperature hot water hydronic heating system.

Figure 4-9h. DDC control system ladder diagram for central plant high-temperature hot water hydronic heating system.

Figure 4-9i. DDC control system equipment for central plant high-temperature hot water hydronic heating system.

Figure 4-9j. DDC control system I/O table and data terminal strip layout for central plant high-temperature hot water hydronic heating system.

b. General Sequence of Operation.

(1) The primary pumping system and the high-temperture hot water converter operate continuously whenever the outside air temperature is low enough for the building to require heating. When this occurs, an outside air temperature controller starts the primary pump, enables the high-temperature hot water converter's control system, and enables the secondary pumps to operate. The outside air temperature controller raises the primary hot water supply temperature as the outside air temperature falls.

(2) The primary hot water supply temperature controller maintains its setpoint by modulating the high-temperature hot water converter valve to maintain the scheduled primary hot water supply temperature.

(3) During the occupied mode, the secondary hot water pumps run whenever the primary hot water pump runs. Each zone temperature controller modulates its zone control valve to blend water from the primary hot water supply with secondary hot water return in order to maintain the zone space temperature setpoint, which is adjustable by the zone occupant.

(4) During the unoccupied mode, the secondary hot water pumps are cycled by the zone night thermostat to maintain the low limit setpoint and to prevent freezing. During this mode, the controller setpoint is determined by an adjustment within the system's HVAC control panel.

c. Detailed Sequence of Operation.

(1) Outside air temperature transmitter TT-XX-01 signals outdoor air temperature to temperature controller TC-XX-01. On a fall in outside air temperature to 16 degrees C (60 degrees F), the process variable (PV) contacts of TC-XX-01 close to energize relays R-XX-04 and R-XX-05, and to turn on pilot light PL-XX-02. The contacts of relay R-XX-04 energize the primary hot water pump, and the contacts of relay R-XX-05 enable the secondary pumps. The auxiliary contacts of the primary pump starter energize relay R-XX-06. The contacts of relay R-XX-06 allow the primary water temperature control system to operate.

(2) On a rise in outside air temperature to 17 degrees C (62 degrees F), the PV contacts of controller TC-XX-01 open to de-energize relay R-XX-04 to stop the primary pump, and relay R-XX-05 to

stop both secondary pumps. The auxiliary contacts of the primary pump starter open, de-energizing relay R-XX-06. The contacts of relay R-XX-06 remove valve VLV-XX-01 from control, and it closes.

(3) Controller TC-XX-01 raises the setpoint of primary hot water supply temperature controller TC-XX-02 as the outside air temperature falls, and lowers the setpoint as outside air temperature rises.

(4) Temperature transmitter TT-XX-02 signals the primary hot water supply temperature to temperature controller TC-XX-02. Controller TC-XX-02 maintains its setpoint by varying its signal to current-to-pneumatic transducer IP-XX-01. The pneumatic signal from IP-XX-01 modulates high-temperature hot water converter valve VLV-XX-01 to maintain the primary supply water temperature setpoint of controller TC-XX-02.

(5) Temperature transmitter TT-XX-03 signals the zone space temperature to controller TC-XX-03. Controller TC-XX-03 maintains its setpoint by varying its current output signal to transducer IP-XX-02. The pneumatic signal from IP-XX-02 modulates secondary zone control valve VLV-XX-02, which mixes primary supply water with secondary return water to maintain the zone space temperature setpoint. The temperature control loop for the other secondary zone functions identically.

(6) Throughout the occupied mode, the contacts of time clock CLK-XX-01 are closed to energize relays R-XX-01, R-XX-02, and R-XX-03, and to turn on pilot light PL-XX-01. The contacts of relay R-XX-01 connect temperature setpoint device TSP-XX-01 to allow manual adjustment of the setpoint of temperature controller TC-XX-03. Relay R-XX-02 provides the same function for TSP-XX-03 in adjustment of controller TC-XX-04. Relay R-XX-03 closes contacts in the starter control circuits of the secondary pumps. The secondary system pumps will start whenever the contacts of relay R-XX-03 (occupied) and R-XX-05 (heating) are closed in their respective pump starter circuits.

(7) During the unoccupied mode, the contacts of time clock CLK-XX-01 are open and de-energize relays R-XX-01, R-XX-02, and R-XX-03, and pilot light PL-XX-01 turns off. The transfer of the contacts of relay R-XX-01 transfers the temperature setpoint adjustment of TC-XX-03 from TSP-XX-01 to TSP-XX-02. The transfer of the contacts of relay R-XX-02 transfers TC-XX-04 temperature setpoint adjustment from TSP-XX-03 to TSP-XX-04. The contacts of relay R-XX-03 open the secondary pump starter circuits to place the secondary pumps under the respective night thermostats TSL-XX-01 and TSL-XX-02. When the zone space temperature falls to 13 degrees C (55 degrees F), the zone secondary pump is energized and remains energized until the temperature rises to 14 degrees C (57 degrees F).

d. Sequence of operation for DDC applications.

(1) The DDC system shall accept a signal from a sunshielded outside air temperature sensing element and transmitter located as shown. The DDC system shall start and stop the pumps at the outside air temperatures shown. The DDC system shall reset the hydronic heating supply temperature setpoint in a linear schedule based on the outside air temperature as shown. The DDC system shall accept a signal from a temperature sensing element and transmitter located in the hydronic heating supply line and the DDC system output shall modulate the converter high-temperature hot water control valve to maintain the reset schedule setpoint in the hydronic heating supply line.

(2) When the system time schedule places the system in the occupied mode, a space temperature sensing element and transmitter located as shown shall signal the DDC system, which shall

maintain the space temperature setpoint as shown by modulating the secondary hydronic system zone valve.

(3) When the system is in the unoccupied mode, the space temperature setpoint shall be as shown.

14. CENTRAL PLANT STEAM DUAL-TEMPERATURE HYDRONIC CONTROL SYSTEM.

a. Description of the hydronic system. This hydronic heating and cooling system consists of hot water from a steam converter, chilled water from a central plant, and related pumping systems. Figures 4-10a through 4-10f show the system design for this type of heating system using a SLDC control panel. Figures 4-10g through 4-10j show the system design for this type of heating system using DDC controls.

Figure 4-10a. Control system schematic for central plant steam dual-temperature hydronic system.

Figure 4-10b. Control system ladder diagram for central plant steam dual-temperature hydronic system.

Figure 4-10c. Control system equipment for central plant steam dual-temperature hydronic system.

Figure 4-10d. Control panel interior door layout for central plant steam dual-temperature hydronic system.

Figure 4-10e. Control panel back panel layout for central plant steam dual-temperature hydronic system.

Figure 4-10f. Control panel terminal block layout for central plant steam dual-temperature hydronic system.

Figure 4-10g. DDC control system schematic for central plant steam dual-temperature hydronic system.

Figure 4-10h. DDC control system ladder diagram for central plant steam dual-temperature hydronic system.

Figure 4-10i. DDC control system equipment for central plant steam dual-temperature hydronic system.

Figure 4-10j. DDC control system I/O table and data terminal strip layout for central plant steam dual-temperature hydronic system.

b. General sequence of operation.

(1) Heating and cooling modes are manually selected.

(2) When the system is in the heating mode, the pumping system and the converter operate continuously whenever the outside air temperature is low enough for the building to require heating. When this occurs, an outside air temperature controller starts the system pump, and the converter control is activated. The outside air temperature controller raises the hot water supply temperature as the outside air temperature falls.

(3) The hot water supply temperature controller maintains its setpoint by modulating the converter valve to maintain the scheduled temperature.

(4) When the system is indexed to cooling, the converter valve closes. The pump continues to run for cooldown and when the return water temperature falls to 29 degrees C (85 degrees F), the changeover valves transfer the water flow from the converter to the central plant chilled water system.

(5) As long as the heating/cooling switch is indexed to cooling, the pump will be energized during the occupied mode and de-energized during the unoccupied mode.

c. Detailed sequence of operation.

(1) Manual switch HS-XX-02 provides for indexing the system to the heating or the cooling mode.

(2) When heating/cooling switch HS-XX-02 is indexed from heating to cooling, relay R-XX-02 is de-energized, and relay R-XX-05 is energized. Contacts of relay R-XX-05 open, removing control from the converter valve, which then closes. Through the normally closed contacts of relay R-XX-02 and the normally open contacts of relay R-XX-06, pump relay R-XX-07 is energized and the pump runs to distribute the hot water in order to reduce its temperature. When the return water temperature falls to the setpoint of TSL-XX-01, the solenoid actuated pneumatic valve EP-XX-01 and relay R-XX-06 are energized, and cooling pilot light PL-XX-03 is turned on. Through EP-XX-01, changeover valves VLV-XX-02 and VLV-XX-03 stop the flow to and from the converter, and open the system to the central plant chilled water system. The normally closed contacts of relay R-XX-06 (line 13) open to stop the pump, but the normally open contacts of that relay (line 12) close. If occupied relay R-XX-01 is energized, the pump continues to run.

(3) Throughout the cooling mode, pump relay R-XX-07, through the normally closed contacts of relay R-XX-02 and the normally open contacts of relay R-XX-06, is energized during the occupied mode and de-energized during the unoccupied mode by the contacts of relay R-XX-01.

(4) When heating/cooling switch HS-XX-02 is indexed from cooling to heating, relays R-XX-05 and R-XX-06 and solenoid actuated pneumatic valve EP-XX-01 are de-energized, cooling pilot light PL-XX-03 is turned off, and relay R-XX-02 is energized. When EP-XX-01 is de-energized, valves VLV-XX-02 and VLV-XX-03 open the system to the converter and close it to the central plant chilled water system.

(5) On a fall in outside air temperature to the setpoint of the PV contacts of controller TC-XX-01, relay R-XX-04 is energized and heating pilot light PL-XX-02 is turned on. The contacts of relay R-XX-04 (line 11), which are closed throughout the heating mode, energize relay R-XX-07. The contacts of relay R-XX-07 energize the system pump. Pump starter auxiliary contacts, through the normally closed contacts of relay R-XX-05 (line 4) energize relay R-XX-03, and the contacts of relay R-XX-03 connect the output of temperature controller TC-XX-02 to current-to-pneumatic transducer IP-XX-01. The transducer output modulates hot water converter valve VLV-XX-01. On a rise in outdoor air temperature to 17 degrees C (62 degrees F), the PV contacts of controller TC-XX-01 open, and relay R-XX-04 is de-energized, de-energizing relay R-XX-07 and stopping the pump. Pump starter auxiliary contacts remove the converter valve from control, and the converter valve closes.

(6) Outside air controller TC-XX-01 raises the setpoint of hot water supply temperature controller TC-XX-02 as the outside air temperature falls and lowers the setpoint as the outside air temperature rises.

(7) Temperature controller TC-XX-02, with its temperature transmitter in the hot water supply piping, through current-to-pneumatic transducer IP-XX-01, modulates high-temperature hot water converter valve VLV-XX-01 to maintain the supply water temperature setpoint of controller TC-XX-02.

d. Sequence of operation for DDC applications.

(1) Switch HS-XX-01 provides for manual switching of the dual-temperature hydronic system between the heating and cooling modes.

(2) When the heating mode is selected, the system changeover valves shall close to the central plant chilled water flow and shall open to flow through the converter, and the distribution pump shall be under control of the DDC system. The DDC system shall accept a signal from a sunshielded outside air temperature sensing element and transmitter located as shown. The DDC system shall start and stop pump at the outside air temperatures shown. The DDC system shall reset the hydronic heating supply temperature setpoint in a linear schedule based on the outside air temperature. The DDC system shall accept a signal from a temperature sensing element and transmitter located in the hydronic heating supply line and the DDC system output shall modulate the converter's steam control valve to maintain the reset schedule setpoint in the hydronic heating supply line.

(3) When the cooling mode is selected, the converter steam valve shall be closed. The DDC system shall accept a signal from a temperature sensing element and transmitter located in the system return. The DDC system shall continue to operate pump to circulate water through the system. When the system return water temperature drops below the setpoint shown, the DDC system shall allow the changeover valves to close to flow through the converter and to open to the central plant chilled water flow, and place the control of pump under control of the system time schedule. During the occupied mode, pump shall operate continuously. In the unoccupied mode, pump shall stop.

15. CENTRAL PLANT HIGH-TEMPERATURE HOT WATER DUAL-TEMPERATURE HYDRONIC CONTROL SYSTEM.

a. Description of the hydronic system. This hydronic heating and cooling system consists of hot water from a high-temperature hot water converter, chilled water from a central plant, and related pumping systems. Figures 4-11a through 4-11f show the system design for this type of heating system using a SLDC control panel. Figures 4-11g through 4-11j show the system design for this type of heating system using DDC controls.

Figure 4-11a. Control system schematic for central plant high-temperature hot water dual-temperature hydronic system.

Figure 4-11b. Control system ladder diagram for central plant high-temperature hot water dual-temperature hydronic system.

Figure 4-11c. Control system equipment for central plant high-temperature hot water dual-temperature hydronic system.

b. General sequence of operation.

(1) Heating and cooling modes are manually selected.

(2) When the system is in the heating mode, as selected by a panel-mounted HEATING/COOLING switch, the pumping system and the high-temperature hot water converter operate continuously whenever the outside air temperature is low enough for the building to require heating. This temperature is to be selected by the designer. When this condition is met, an outside air temperature controller starts the system pump, and the converter is under control. As the outside air temperature rises and falls, the outside air temperature controller resets the hot water supply temperature setpoint in accordance with a schedule established by the designer.

(3) The hot water supply temperature controller maintains the scheduled hot water supply temperature setpoint by modulating the high temperature hot water converter valve.

(4) When the system heating/cooling switch is indexed to cooling, the converter valve closes. The pump continues to run for cooldown of the system water. When the return water temperature falls to 29 degrees C (85 degrees F), the changeover valves divert the water flow from the converter to the central plant chilled water system.

(5) As long as the switch HS-XX-02 is indexed to cooling, the pump will be energized during the occupied mode and de-energized during the unoccupied mode.

c. Detailed sequence of operation.

(1) Manual HEATING/COOLING switch HS-XX-02 allows for indexing of the system between the heating and the cooling modes.

(2) When switch HS-XX-02 is indexed from heating to cooling, relays R-XX-02 and R-XX-03 are de-energized which causes the converter valve to close and the system pump to momentarily shut down. Simultaneously, relay R-XX-04 is energized, causing its normally open contact on Line 10 to close. Assuming that the temperature of the return water is above the setpoint of TSL-XX-01, the system pump is operated through the normally closed contact of relay R-XX-05 on Line 11. The pump continues to run until the temperature of the return water cools down below the setpoint of TSL-XX-01. When this occurs, pilot light PL-XX-03 (COOLING) is lit and relay R-XX-05 is energized which allows the pump to stop and energizes solenoid actuated pneumatic valve EP-XX-01 on Line 12. When EP-XX-01 is energized, two-position changeover valves VLV-XX-02 and VLV-XX-03 close to the hot water converter and open to the central plant chiller. Hereafter, the system pump operates through the contacts of relay R-XX-01 only when the system is in the occupied mode.

(3) When hand switch HS-XX-02 is indexed from cooling to heating, EP-XX-01 and relays R-XX-04 and R-XX-05 are de-energized and cooling pilot light PL-XX-03 is turned off. When EP-XX-01 is denergized, changeover valves VLV-XX-02 and VLV-XX-03 open to the conveter and close to the central plant chilled water system.

(4) On a fall in outdoor air temperature to the setpoint of the PV contacts of outside air temperature reset controller TC-XX-01, relay R-XX-03 is energized and heating pilot light PL-XX-02 is lit. The pump is started through the normally open contacts of relay R-XX-03 (Line 9). When the pump starter is energized, its auxiliary contacts (M01 on Line 3) close. This energizes relay R-XX-02 whose normally open contacts close to allow the output of temperature controller TC-XX-02 to be received by current-to-pneumatic transducer IP-XX-01. On a rise in outdoor air temperature to 18 degrees C (65 degrees F) the PV contacts of temperature controller TC-XX-01 open and relay R-XX-03 is de-energized, stopping the pump. The pump starter's auxiliary contacts open, which de-energizes relay R-XX-02 and causes the converter valve to close.

(5) Outside air temperature reset controller TC-XX-01 raises the setpoint of hot water supply temperature controller TC-XX-02 as the outside air temperature falls and lowers the setpoint as the outside air temperature rises.

(6) Temperature transmitter TT-XX-02 sends a hot water supply temperature signal to temperature controller TC-XX-02. Temperature controller TC-XX-02 maintains its setpoint by varying its output to current-to-pneumatic transducer IP-XX-01. The pneumatic signal from IP-XX-01 modulates high temperature hot water converter valve VLV-XX-01 to maintain the hot water supply temperature setpoint of temperature controller TC-XX-02.

d. Sequence of operation for DDC applications.

(1) Switch HS-XX-01 provides for manual switching of the dual-temperature hydronic system between the heating and cooling modes.

(2) When the heating mode is selected, the system changeover valves shall close to the central plant chilled water flow and shall open to flow through the converter, and the distribution pump shall be under control of the DDC system. The DDC system shall accept a signal from a sunshielded outside air temperature sensing element and transmitter located as shown. The DDC system shall start and stop pump at the outside air temperatures shown. The DDC system shall reset the hydronic heating supply temperature setpoint in a linear schedule based on the outside air temperature as shown. The DDC

system shall accept a signal from a temperature sensing element and transmitter located in the hydronic heating supply line and the DDC system output shall modulate the converter's high-temperature hot water control valve to maintain the reset schedule setpoint in the hydronic heating supply line.

(3) When the cooling mode is selected, the converter high-temperature hot water control valve shall be closed. The DDC system shall accept a signal from a temperature sensing element and transmitter located in the system return as shown. The DDC system shall continue to operate pump to circulate water through the system. When the system return water temperature drops below the setpoint shown, the DDC system shall allow the changeover valves to close to flow through the converter and to open to the central plant chilled water flow, and place the control of pump under control of the system time schedule. During the occupied mode, pump shall operate continuously. In the unoccupied mode, pump shall stop.

16. SINGLE BUILDING DUAL-TEMPERATURE HYDRONIC CONTROL SYSTEM.

a. Description of the hydronic system. This hydronic heating and cooling system consists of a boiler, chiller, pump and distribution piping. This system varies the hot water flow through the boiler. Therefore, it can be used only with boilers that are not sensitive to flow variation. A variation of this system which utilizes constant flow through the boiler is depicted in Chapter 5. Figures 4-12a through 4-12f show the control system design for this type of hydronic system using a SLDC control panel. Figures 4-12g through 4-12j show the control system design for this type of hydronic system using DDC controls.

Figure 4-12a. Control system schematic for single building dual-temperature hydronic system.

Figure 4-12b. Control system ladder diagram for single building dual-temperature hydronic system.

Figure 4-12c. Control system equipment for single building dual-temperature hydronic system.

Figure 4-12d. Control panel interior door layout for single building dual-temperature hydronic system.

Figure 4-12e. Control panel back panel layout for single building dual-temperature hydronic system.

Figure 4-12f. Control panel terminal block layout for single building dual-temperature hydronic system.

Figure 4-12g. DDC control system schematic for single building dual-temperature hydronic system.

Figure 4-12h. DDC control system ladder diagram for single building dual-temperature hydronic system.

Figure 4-12i. DDC control system equipment for single building dual-temperature hydronic system.

Figure 4-12j. DDC control system I/O table and data terminal strip layout for single building dual-temperature hydronic system.

b. General sequence of operation.

(1) Heating and cooling modes are manually selected at the control panel. The position of the dual-temperature changeover valves is manually selected at the control panel.

(2) When the system is indexed to heating, the boiler and pump operate continuously whenever the outside air temperature is low enough for the building to require heating. When this occurs, the system boiler is started and the system pump is energized. The boiler functions under its own control system to maintain a constant boiler water temperature.

(3) The control system modulates a three-way valve to mix supply and return hot water to maintain the scheduled hot water supply temperature setpoint. As the outside air temperature falls the supply water temperature is raised.

(4) When the system is indexed from the heating mode to the cooling mode, the boiler is shut down. The pump continues to run to dissipate the heat from the piping system and the boiler until the return water temperature drops below the setpoint of the return water thermostat. When this occurs, the distribution pump stops and the changeover valves are then permitted to close to the boiler and open to the chiller.

(5) When the system is indexed to cooling and changeover has occurred, the chiller and pump are energized during the occupied mode. At the conclusion of the occupied period, the chiller is de-energized but the pump continues to circulate water for a period of time while the chiller completes its shutdown cycle, and then the pump stops.

(6) When the system is indexed from cooling mode to heating mode, the chiller enters its shutdown cycle and the pump continues to circulate water through the chiller for a period of time while the chiller completes its shutdown cycle.

c. Detailed sequence of operation.

(1) Switch HS-XX-02 allows for manual indexing of the dual-temperature hydronic system between the heating and cooling modes. Switch HS-XX-03 allows for manual operation of the dual-temperature changeover valves.

(2) When switch HS-XX-02 is indexed from the heating mode to the cooling mode, relays R-XX-02 and R-XX-03 are de-energized, heating pilot light PL-XX-02 is turned off, and time-delay relay TDR-XX-01 is energized. One set of normally open contacts of relay R-XX-03 (Line 200) open to de-energize the boiler and a second set of normally open contacts open to interrupt the input signal to IP-XX-01. A set of normally open contacts of relay R-XX-02 on Line 13 open and normally open contacts of time-delay relay TDR-XX-01 on Line 14 close, transferring control of pump relay R-XX-06 from the heating mode to the cooling mode. If the return water temperature is above the setpoint of TSL-XX-01, relay R-XX-04 (Line 9) remains de-energized. As a result, its normally closed contact on Line 8 remains closed and the pump continues circulating water through the system to dissipate heat. When the temperature of the return water falls below the setpoint of TSL-XX-01, relay R-XX-04 is energized. The normally closed contacts of relay R-XX-04 on line 8 are now open, de-energizing time-delay relay TDR-XX-01. Once the time-delay period expires, the normally open contacts of TDR-XX-01 on line 14 open, de-energizing relay R-XX-06, causing the pump to stop. When relay R-XX-04 is energized as a result of the return water temperature falling below the setpoint of TSL-XX-01, a set of normally open contacts on line 12 are closed, which allows EP-XX-01 to become energized, when switch HS-XX-03 is in the "cooling" position, causing the changeover valves to open to the chiller.

(3) When the system enters the occupied mode, as determined by timeclock CLK-XX-01 on Line 0, relay R-XX-01 on Line 1 is energized and pilot light PL-XX-01 (OCCUPIED) is lit. When relay R-XX-01is energized, the normally open contact on Line 7 is closed, which energizes time-delay relay

TDR-XX-01. The normally open contacts of TDR-XX-01 on line 14 close, which energizes relay R-XX-06, causing the system pump to start. Relay R-XX-01 also has a set of normally open contacts on line 10 which are closed during the occupied mode. This causes the chiller to be enabled, if flow through the chilled water loop is proven by flow switch FS-XX-02, and pilot light PL-XX-03 (COOLING) is lit.

(4) When the occupied period ends, relay R-XX-01 is de-energized. The contact on line 10 opens to de-energize R-XX-05 and PL-XX-03. This causes the chiller to shut down. The normally open contact of relay R-XX-01 on line 7 also opens, de-energizing time-delay relay TDR-XX-01. The normally open contact of TDR-XX-01 on line 14 remains closed until the expiration of the time delay, allowing the pump to continue running while the chiller completes its shut-down process. After the time-delay period expires, this contact opens, de-energizing relay R-XX-06 and thereby shutting off the pump.

(5) When switch HS-XX-02 is indexed from the cooling mode to the heating mode, relays R-XX-04, R-XX-05, and TDR-XX-01 are de-energized. As a result, the chiller is shut down and PL-XX-03 is turned off. The pump continues to run until the expiration of the time delay period of TDR-XX-01.

(6) With the system indexed to the heating mode, if the outside air temperature is below the PV alarm setpoint of temperature controller TC-XX-01, the controller's PV contact on Line 3 will be closed. This energizes relay R-XX-02 to start the system pump. Once flow is proven through the heating loop by flow switch FS-XX-01, relay R-XX-03 is energized and pilot light PL-XX-02 (HEATING) is lit. R-XX-03 starts the boiler (Line 200) and also closes a contact between TC-XX-02 and IP-XX-01, placing valve VLV-XX-01 under the control of temperature controller TC-XX-02.

(7) Temperature transmitter TT-XX-02 sends a hot water supply temperature signal to temperature controller TC-XX-02. Controller TC-XX-02 maintains its setpoint by varying its output signal to current-to-pneumatic transducer IP-XX-01. The pneumatic output from IP-XX-01 modulates three-way valve VLV-XX-01 to mix boiler water and return water to maintain the temperature setpoint of controller TC-XX-02. Outside air temperature transmitter TT-XX-01 sends an outside air temperature signal to temperature controller TC-XX-01. As the outside air temperature falls, TC-XX-01 raises the setpoint of controller TC-XX-02.

d. Sequence of operation for DDC applications.

(1) Switch HS-XX-01 provides for manual indexing of the dual-temperature hydronic system between the heating and cooling modes.

(2) When the heating mode is selected, the chiller shall be stopped. The distribution pump shall continue to operate until the expiration of a time delay as recommended by the chiller manufacturer. At the expiration of the time delay, the system changeover valves shall close to flow through the chiller and shall open to flow through the boiler, and the distribution pump shall be under control of the DDC system. The DDC system shall accept a signal from a sunshielded outside air temperature sensing element and transmitter located as shown. The DDC system shall start and stop the distribution pump and the boiler at the outside air temperatures shown. The DDC system shall reset the hydronic heating supply temperature setpoint in a linear schedule based on the outside air temperature as shown. The DDC system shall accept a signal from a temperature sensing element and transmitter located in the hydronic supply line and the DDC system output shall modulate the hydronic heating system control valve to maintain the reset schedule setpoint in the hydronic heating supply line.

(3) When the cooling mode is selected, the boiler shall be stopped. The DDC system shall accept a signal from a temperature sensing element and transmitter located in the system supply as

shown. The DDC system shall continue to operate the distribution pump to circulate water through the system with the boiler shut off. When the system supply water temperature drops below the setpoint shown, the DDC system shall allow the changeover valves to close to flow through the boiler and to open to flow through the chiller, and shall place the chiller and the distribution pump under control of the system time schedule. During the occupied mode, the distribution pump shall operate continuously and the chiller shall be permitted to operate. When the system is in the unoccupied mode, the chiller shall shut down. The distribution pump shall continue to operate until the expiration of the time delay.

17. HEATING AND VENTILATING CONTROL SYSTEM.

a. Description of the heating and ventilating system. This air handling system consists of a supply fan, outside air, return air and relief air dampers, a filter, and a heating coil. Figures 4-13a through 4-13f show the control system design for this type of air handling system using a SLDC control panel. Figures 4-13g through 4-13j show the control system design for this type of air handling system using DDC controls.

Figure 4-13a. Control system schematic for heating and ventilating system.

Figure 4-13b. Control system ladder diagram for heating and ventilating system.

Figure 4-13c. Control system equipment for heating and ventilating system.

Figure 4-13d. Control panel interior door layout for heating and ventilating system.

Figure 4-13e. Control panel back panel layout for heating and ventilating system.

Figure 4-13f. Control panel terminal block layout for heating and ventilating system.

Figure 4-13g. DDC control system schematic for heating and ventilating system.

Figure 4-13h. DDC control system ladder diagram for heating and ventilating system.

Figure 4-13i. DDC control system equipment for heating and ventilating system.

Figure 4-13j. DDC control system I/O table and data terminal strip layout for heating and ventilating system.

b. General sequence of operation.

(1) Supply fan off. When the fan is off, the outside air and relief air dampers are closed and the return air damper is open. The heating coil valve is under the control of the space temperature controller.

(2) Supply fan operating. When the supply fan is on, the control dampers and the heating coil valve are operated as required by the system's mode of operation. The control dampers are either positioned for full recirculation of air, positioned to introduce minimum outside air, or modulated in sequence with the heating coil to maintain space temperature. The heating coil is modulated by the space temperature controller.

(3) Control of the supply fan. Unless the fan is stopped as the result of a safety shutdown, it is on or off as required by the control system's mode of operation.

(4) Safety shutdown of the fans. The control system shuts down the fans if there is a low temperature condition or smoke is detected.

(5) Low temperature detection. On a fall in temperature to its setpoint, a low temperature protection thermostat stops the supply fan. To restart the fan, the thermostat and the control panel must be manually reset.

(6) Smoke detection. Duct smoke detectors in the supply and return air stop the supply fan whenever either detects the presence of smoke. To restart the fan, the smoke detectors and control panel must be manually reset.

(7) Filter condition. Filter condition is monitored by a pressure gauge and a differential pressure switch. On a rise in pressure drop across the filter to the switch setpoint, the switch turns on a pilot light.

(8) Unoccupied mode of operation. Throughout the unoccupied mode, the outside air and relief air dampers remain closed and the return air damper remains open. The supply fan is cycled by the system's night thermostat to maintain its low limit space temperature setpoint.

(9) Ventilation delay mode of operation. During the ventilation delay mode, the dampers remain as they were throughout the unoccupied mode and the supply fan runs continuously. Until the ventilation delay mode ends, the HVAC system circulates return air to bring the building to comfort conditions, using a minimum of energy.

(10) Occupied mode of operation. The supply fan runs continuously. The heating coil valve and control dampers are modulated, with a deadband between them, by the space temperature controller.

c. Detailed sequence of operation.

(1) Time clock CLK-XX-01 has two independent sets of contacts, which between them determine the mode under which the system operates. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-03 and turning on pilot light PL-XX-02. The normally closed contacts of relay R-XX-03 open, to prevent relay R-XX-02 from being energized. The normally open contacts of relay R-XX-02 prevent signals from reaching current-to-pneumatic transducer IP-XX-01. The dampers remain in their normal positions, with outside air and relief air dampers closed and return air damper open.

(2) When the occupied contacts of time clock CLK-XX-01 close, relay R-XX-01 is energized and pilot light PL-XX-01 is turned on. Contacts of relay R-XX-01 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-04.

(3) When the ventilation delay contacts of time clock CLK-XX-01 open to end the ventilation delay mode, relay R-XX-03 is de-energized and pilot light PL-XX-02 is turned off. With the now closed but normally open contacts of energized relays R-XX-01 and R-XX-04, the normally closed contacts of relay R-XX-03 energize relay R-XX-02. The normally open contacts of relay R-XX-02 connect the output signal of high signal selector TY-XX-01 to current-to-pneumatic transducer IP-XX-01. The pneumatic output of transducer IP-XX-01 places the dampers at the minimum position set on minimum position

switch MPS-XX-01 or under control of space temperature controller TC-XX-01, whichever signal is higher.

(4) Temperature controller TC-XX-01, with its temperature transmitter in the space served, through current-to-pneumatic transducer IP-XX-02, modulates heating coil valve VLV-XX-01, and during the occupied mode after the expiration of the ventilation delay mode, modulates the control dampers in sequence with the heating coil valve to maintain the temperature controller setpoint.

(5) On a fall in temperature to its setpoint, low temperature protection thermostat TSL-XX-01 opens a set of closed contacts in the supply fan circuit, de-energizing the supply fan. Through its open contacts, thermostat TSL-XX-01 energizes relay R-XX-05 and lights pilot light PL-XX-04. The contacts of relay R-XX-05 energize relay R-XX-07. The normally closed contacts of relay R-XX-07 de-energize the supply fan, the normally open contacts lock in relay R-XX-07. To restart the fan after a low temperature shutdown, both the low temperature protection thermostat TSL-XX-01 and the control panel must be reset. The control panel is reset by depressing manual switch HS-XX-02.

(6) Whenever smoke detector SMK-XX-01 or smoke detector SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan start circuit open, de-energizing the fan. The normally open contacts close, energizing relay R-XX-06 and lighting pilot light PL-XX-05. Normally open contacts of relay R-XX-06 close, energizing relay R-XX-07. Normally closed contacts of relay R-XX-07 in the supply fan start circuit open, and the normally open contacts close to lock in relay R-XX-07. To restart the fan after a smoke shutdown, smoke detectors SMK-XX-01 and/or SMK-XX-02 and the control panel must be reset. The control panel is reset by depressing manual switch HS-XX-02.

(7) Differential pressure gauge DPI-XX-01 across the filter provides local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-01 turns on pilot light PL-XX-03.

(8) At the conclusion of the occupied mode, the occupied contacts of time clock CLK-XX-01 open, and relay R-XX-01 is de-energized. The contacts of relay R-XX-01 open, de-energizing the supply fan and placing it under the control of the night thermostat TSL-XX-02.

d. Sequence of operation for DDC applications.

(1) Ventilation delay mode timing shall start prior to the occupied mode timing. During ventilation delay mode, the DDC system shall prevent the outside air damper from opening. At the time shown, the DDC system shall place the system in the occupied mode. At the expiration of the ventilation delay mode timing period, the DDC system shall place the outside air, return air, and relief air dampers under space temperature control. At the time shown, the DDC system shall place the control system in the unoccupied mode of operation and the dampers shall return to their normal positions.

(2) During occupied and ventilation delay modes the supply fan shall operate continuously. During unoccupied mode the supply fan shall cycle according to the night setback schedule. The fan shall start and stop at the setpoints as shown.

(3) A differential pressure switch across the filter shall initiate a filter alarm when the pressure drop across the filter exceeds the setpoint as shown.

(4) A freezestat, located as shown, shall stop the supply fan, cause the outside air, return air, and relief air dampers to return to their normal position, and shall initiate a low temperature alarm if the

temperature drops below the freezestat's setpoint. Return to the normal mode of operation shall require manual reset at the freezestat. The DDC panel shall monitor the freezestat through auxiliary contacts and shall indicate an alarm condition when the freezestat trips.

(5) A space temperature sensing element and transmitter operating through the DDC system shall first gradually shut off the heating coil valve. After the heating coil valve is fully closed, the DDC system shall then gradually operate the outside air damper to admit outside air beyond the minimum quantity to maintain the setpoint as shown.

(6) Smoke Detectors in the supply air and return air ductwork shall stop the supply fan and initiate a smoke alarm if smoke is detected at either location. Restarting the supply fan shall require manual reset at the smoke detector.

18. MULTIZONE HVAC CONTROL SYSTEM WITH RETURN FAN.

a. Description of the HVAC system. This is an air handling system with supply and return fans, economizer dampers, a cold deck with a cooling coil, a hot deck with a heating coil, individual zone mixing dampers, and individual zone heating controls. Figures 4-14a through 4-14f show the control system design for this type of air handling system using a SLDC control panel. Figures 4-14g through 4-14j show the control system design for this type of air handling system using DDC controls. Note that because a two-deck multizone system has no deadband between heating and cooling, the decision to use an economizer cycle with this type system needs to be evaluated in accordance with the guidance presented in chapter three.

Figure 4-14a. Control system schematic for multizone HVAC system.

Figure 4-14b. Control system ladder diagram for multizone HVAC system.

Figure 4-14c. Control system equipment for multizone HVAC system.

Figure 4-14d. Control panel interior door layout for multizone HVAC system.

Figure 4-14e. Control panel back panel layout for multizone HVAC system.

Figure 4-14f. Control panel terminal block layout for multizone HVAC system.

Figure 4-14g. DDC control system schematic for multizone HVAC system.

Figure 4-14h. DDC control system ladder diagram for multizone HVAC system.

Figure 4-14i. DDC control system equipment for multizone HVAC system.

Figure 4-14j. DDC control system I/O table and data terminal strip layout for multizone HVAC system.

b. General sequence of operation.

(1) Supply and return fans off. When the fans are off, the cooling coil valve and the outside air and relief air dampers are closed. The return air damper is open. The heating coil valve is modulated

under the control of the hot deck temperature controller. Zone dampers are under the control of their zone thermostats.

(2) Supply and return fans operating. When the fans are on, the control dampers are either positioned for full recirculation of air, positioned to introduce minimum outside air, or modulated to maintain mixed air temperature. The cooling coil valve is either closed or modulated to maintain the cold deck discharge temperature. The heating coil valve is modulated to maintain the hot deck discharge temperature. Zone dampers are under the control of their zone thermostats.

(3) Control of supply fan and return fan. Unless the fans are stopped as the result of a safety shutdown, they are on or off as required by the control system's mode of operation.

(4) Safety shutdown of the fans. The control system shuts down the fans if there is a low temperature condition or if smoke is detected.

(5) Low temperature detection. On a fall in temperature to its setpoint, a low temperature protection thermostat stops the supply and return fans. To restart the fans, the thermostat and the control panel must be manually reset.

(6) Smoke detection. Duct smoke detectors stop the supply and return fans whenever either detects the presence of smoke. To restart the fans, the smoke detectors and control panel must be manually reset.

(7) Filter condition. Filter condition is monitored by a pressure gauge and a differential pressure switch. On a rise in pressure drop across the filter to the switch setpoint, the switch turns on a pilot light.

(8) Economizer control. When the control system mode of operation no longer requires the outside air, return air, and relief air dampers to be in their full recirculation operating positions, the dampers are positioned to admit outside air for ventilation. The dampers then remain at minimum position until the economizer controller closes both its PV and DEV contacts. The economizer controller closes its PV contacts when the outside air temperature indicates that the building requires cooling rather than heating. The economizer controller closes its DEV contacts when the outside air temperature is sufficiently below the return air temperature to be effective for cooling. When both these contacts close, the dampers are modulated by the mixed air temperature controller.

(9) Mixed air temperature control. A mixed air temperature controller with its temperature transmitter in the mixed air modulates the outside air and relief air dampers between minimum position and fully open to maintain a mixed air temperature of 13 degrees C (55 degrees F). As the outside air and relief air dampers open, the return air damper closes.

(10) Cold deck temperature control. A cold deck temperature controller with its temperature transmitter in the cold deck discharge modulates the cooling coil valve to maintain its setpoint temperature during the ventilation delay and occupied modes.

(11) Hot deck temperature control. A hot deck temperature controller with its temperature transmitter in the heating coil discharge modulates the heating coil valve to maintain its temperature setpoint. Outside air temperature controller TC-XX-04 with its temperature transmitter in the outside air lowers the setpoint of the hot deck controller as outside air temperature rises. On a fall in outside air temperature, the reverse occurs.

(12) Zone space temperature control. On a rising space temperature, each zone space thermostat modulates the zone mixing damper toward closed to the hot deck and open to the cold deck.

(13) Unoccupied mode of operation. Throughout the unoccupied mode, the outside air and relief air dampers and the cooling coil valve remain closed, and the return air damper remains open. The supply and return fans are cycled by the system's night thermostat to maintain its low limit space temperature setpoint.

(14) Ventilation delay mode of operation. During the ventilation delay mode, the dampers remain as they were throughout the unoccupied mode, and the supply and return fans run continuously. Until the ventilation delay mode ends, the HVAC system circulates return air to bring the building to comfort conditions, using a minimum of energy.

(15) Occupied mode of operation. The supply and return fans run continuously, and the outside air and relief air dampers are at minimum position or are under mixed air temperature control as previously described.

c. Detailed sequence of operation.

(1) Timeclock CLK-XX-01 has two independent sets of contacts, which between them determine the mode under which the system operates. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-04 and lighting pilot light PL-XX-02. The normally closed contacts of relay R-XX-04 open, preventing relay R-XX-03 from being energized. The normally open contacts of relay R-XX-03 prevent any signal reaching current-to-pneumatic transducer IP-XX-01. Thus, the dampers remain in their normal positions, with outside air and relief air dampers closed and return air damper open.

(2) When the timeclock's occupied contacts close, relay R-XX-01 is energized. The contacts of relay R-XX-02 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-05 and, with the contacts of relay R-XX-01, energize relay R-XX-06. The contacts of relay R-XX-06 place the cold deck temperature controller in control of cooling coil valve VLV-XX-01. The outside air and relief air dampers remain closed and the return air damper remains open.

(3) When the ventilation delay contacts of timeclock CLK-XX-01 open to end the ventilation delay mode of operation, relay R-XX-04 is de-energized. The normally closed contacts of relay R-XX-04, in series with the now closed but normally open contacts of relays R-XX-01 and R-XX-05, energize relay R-XX-03. The normally open contacts of relay R-XX-03 connect the output signal of high signal selector TY-XX-01 to current-to-pneumatic transducer IP-XX-01. The pneumatic output of transducer IP-XX-01 places the dampers at the minimum position set on minimum position switch MPS-XX-01, unless relay R-XX-07 is energized. Economizer EC-XX-01 controls the action of relay R-XX-07. The economizer receives signals from outside air temperature transmitter TT-XX-02 and from return air transmitter TT-XX-03. The difference between the return air temperature and the outside air temperature controls the DEV contacts, and the outside air temperature controls the PV contacts. When both these contacts are closed, relay R-XX-07 is energized and pilot light PL-XX-03 is turned on. When relay R-XX-07 is energized, its contacts connect the output of mixed air controller TC-XX-01 to high signal selector TY-XX-01 to modulate the outside air and relief air dampers between minimum position and fully open while modulating the return air damper in the opposite direction to maintain the mixed air temperature controller setpoint.

(4) On a fall in temperature to its setpoint, low temperature protection thermostat TSL-XX-01 opens a set of closed contacts in the supply fan starter circuit, de-energizing the supply fan. The auxiliary contacts of the supply fan starter de-energize relay R-XX-05, and the contacts of relay R-XX-05 in the return fan starter circuit de-energize the return fan. A set of open contacts in low temperature protection thermostat TSL-XX-01 close, energizing relay R-XX-08 and lighting pilot light PL-XX-05. The contacts of relay R-XX-08 energize relays R-XX-10 and R-XX-11. One set of the contacts of relay R-XX-10 locks in relays R-XX-10 and R-XX-11, and another set de-energizes the supply fan. Relay R-XX-11 de-energizes the return fan. To restart the fans after a low temperature shutdown, both the low temperature thermostat TSL-XX-01, and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-02.

(5) When smoke detector SMK-XX-01 or smoke detector SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan starter circuit open, de-energizing the supply fan. The auxiliary contacts of the supply fan starter de-energize relay R-XX-05, and the contacts of relay R-XX-05 in the return fan starter circuit de-energize the return fan. Its normally open contacts close, energizing relay R-XX-09. The normally open contacts of R-XX-09 close, energizing relays R-XX-10 and R-XX-11. One set of contacts of relay R-XX-10 (line 17) locks in relays R-XX-10 and R-XX-11. The other set of contacts of relay R-XX-10 (line 101) de-energizes the supply fan, and the contacts of relay R-XX-11 de-energize the return fan. To restart the fans after a smoke alarm shutdown, smoke detectors SMK-XX-01 and/or SMK-XX-02 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-02.

(6) Differential pressure gauge DPI-XX-01 across the filter provides local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-01 turns on pilot light PL-XX-04.

(7) Temperature controller TC-XX-02, with its temperature transmitter TT-XX-04 in the cooling coil discharge, through the contacts of relay R-XX-06 and current-to-pneumatic transducer IP-XX-02, modulates cooling coil valve VLV-XX-01 to maintain its temperature setpoint. Relay R-XX-06 is energized during the ventilation delay and occupied modes. During the unoccupied mode, R-XX-06 is de-energized, cooling coil valve control is interrupted, and the valve closes.

(8) Hot deck temperature controller TC-XX-03, with its temperature transmitter TT-XX-05 in the heating coil discharge, modulates hot deck heating coil valve VLV-XX-02 to maintain its temperature setpoint. Controller TC-XX-04 with temperature transmitter TT-XX-02 in the outside air raises the setpoint of controller TC-XX-03 on a fall in outside air temperature and lowers it on a rise in outside air temperature.

(9) On a rising zone space temperature, thermostat T-XX-XX modulates damper actuator DA-XX-XX to gradually close the zone damper to the hot deck and open it to the cold deck. The reverse occurs on a falling zone space temperature.

(10) When the occupied contacts of time clock CLK-XX-01 open to end the occupied mode and index the system to the unoccupied mode, relays R-XX-01 and R-XX-02 are de-energized and pilot light PL-XX-01 is turned off. The contacts of relay R-XX-02 open, de-energizing the supply fan and placing the system's night thermostat TSL-XX-02 in control of the supply fan, and, through interlock, in control of the return fan. On a fall in space temperature to 13 degrees C (55 degrees F), the contacts of TSL-XX-02 close, energizing both fans; on a rise in temperature to 16 degrees C (60 degrees F), the contacts open, de-energizing the fans.

d. Sequence of operation for DDC applications.

(1) Ventilation delay mode timing shall start prior to the occupied mode timing. During ventilation delay mode the dampers shall remain in their normal positions as shown, except when under economizer control. At the time shown, the DDC system shall place the system in the occupied mode. At the expiration of the ventilation delay mode timing period, the DDC system shall place the outside air, return air, and relief air dampers under mixed air temperature and economizer control. At the time shown, the DDC system shall place the control system in the unoccupied mode of operation and the dampers shall return to their normal positions as shown.

(2) During occupied and ventilation delay modes the supply fan and return fan shall operate continuously. During unoccupied mode the supply fan and the return fan shall cycle according to the night setback schedule. The fans shall start and stop at the setpoints as shown.

(3) A differential pressure switch across the filter shall initiate a filter alarm when the pressure drop across the filter exceeds the setpoint as shown.

(4) A freezestat, located as shown, shall stop the supply and return fans, cause the outside air, return air, and relief air dampers to return to their normal position, and shall initiate a low temperature alarm if the temperature drops below the freezestat's setpoint. Return to the normal mode of operation shall require manual reset at the freezestat. The DDC panel shall monitor the freezestat through auxiliary contacts and shall indicate an alarm condition when the freezestat trips.

(5) Smoke Detectors in the supply air and return air ductwork shall stop the supply fan and the return fan and initiate a smoke alarm if smoke is detected at either location. Restarting the fans shall require manual reset at the smoke detector.

(6) The DDC system shall modulate the heating coil control valve from the signal of a temperature sensing element and transmitter located in the discharge air of the coil to maintain the hot deck temperature setpoint. A temperature sensing element and transmitter in the outside air intake shall reset the hot deck temperature setpoint with respect to the outside air temperature signal in a linear schedule as shown.

(7) During occupied and ventilation delay modes, the cooling coil control valve shall be modulated by the DDC system from the signal of a temperature sensing element and transmitter located in the coil discharge air to maintain the cold deck temperature setpoint as shown. During the unoccupied mode, the cooling coil control valve shall remain closed.

(8) The DDC system shall accept the signal of an outside air temperature sensing element and transmitter and the signal of a return air temperature sensing element and transmitter. The DDC system shall perform switch over between outside air economizer control mode and minimum outside air mode. Until the outside air temperature rises above the setpoint, the DDC system shall hold the system in the minimum outside air mode. When the outside air temperature rises above the setpoint, the DDC system shall place the AHU in the economizer mode or in the minimum outside air mode as determined by a comparison of the outside air and return air temperatures in accordance with the differential temperature setpoints as shown. When the outside air temperature is low with respect to the return air temperature, the AHU shall be in the economizer mode. When the DDC system places the control system in the minimum outside air mode, the outside air damper shall be open to the minimum outdoor air setting.

When the DDC system places the system in the economizer mode, it shall modulate the dampers from the signal of a temperature sensing element and transmitter in the mixed air stream to maintain the setpoint as shown.

(9) A space temperature sensor for each zone shall signal the DDC system to gradually operate the zone mixing damper to heat and cool its respective zone by mixing cold deck air and hot deck air to maintain the setpoint. On a rise in space temperature, the hot deck damper shall gradually close, and the cold deck damper shall gradually open.

19. DUAL-DUCT HVAC CONTROL SYSTEM WITH RETURN FAN.

a. Description of the HVAC system. This is an air handling system with supply and return fans, economizer dampers, a cold duct with a cooling coil, and a hot duct with a heating coil. In addition, each dual-duct zone has a thermostat and a dual-duct box with damper and damper actuator. Figures 4-15a through 4-15f show the control system design for this type of air handling system using a SLDC control panel. Figures 4-15g through 4-15j show the control system design for this type of air handling system using DDC controls. Note that because a dual-duct multizone system has no deadband between heating and cooling, the decision to use an economizer cycle with this type system needs to be evaluated in accordance with the guidance presented in chapter three.

Figure 4-15a. Control system schematic for dual-duct HVAC system.

Figure 4-15b. Control system ladder diagram for dual-duct HVAC system.

Figure 4-15c. Control system equipment for dual-duct HVAC system.

Figure 4-15d. Control panel interior door layout for dual-duct HVAC system.

Figure 4-15e. Control panel back panel layout for dual-duct HVAC system.

Figure 4-15f. Control panel terminal block layout for dual-duct HVAC system.

Figure 4-15g. DDC control system schematic for dual-duct HVAC system.

Figure 4-15h. DDC control system ladder diagram for dual-duct HVAC system.

Figure 4-15i. DDC control system equipment for dual-duct HVAC system.

Figure 4-15j. DDC control system I/O table and data terminal strip layout for dual-duct HVAC system.

b. General sequence of operation.

(1) Supply and return fans off. When the fans are off, the cooling coil valve and the outside air and relief air dampers are closed. The return air damper is open. The heating coil valve is modulated under the control of the hot duct temperature controller. Dual-duct boxes are under the control of their zone thermostats.

(2) Supply and return fans operating. When the fans are on, the control dampers and the cooling coil and heating coil valves are operated as required by the system's mode of operation. The control dampers are either positioned for full recirculation of air, positioned to introduce minimum outside air, or modulated to maintain mixed air temperature. The cooling coil valve is either closed, or modulated to maintain the cold duct discharge temperature setpoint. The heating coil valve is modulated to maintain the hot duct discharge temperature. Dual-duct boxes are under the control of their thermostats.

(3) Control of supply and return fans. Unless the fans are stopped as the result of a safety shutdown, they are on or off as required by the control system's mode of operation.

(4) Safety shutdown of the fans. The control system shuts down the fans if there is a low temperature condition, or if smoke is detected.

(5) Low temperature detection. On a fall in temperature to its setpoint, a low temperature protection thermostat stops the supply and return fans. To restart the fans, the thermostat and the control panel must be manually reset.

(6) Smoke detection. Duct smoke detectors stop the supply and return fans whenever either detects the presence of smoke. To restart the fans, the smoke detectors and control panel must be manually reset.

(7) Filter condition. Filter condition is monitored by a pressure gauge and a differential pressure switch. When the pressure drop across the filter reaches the switch setpoint, the switch turns on a pilot light.

(8) Economizer control. When the control system's mode of operation no longer requires the outside air, return air, and relief air dampers to be in their full recirculating positions, the dampers are positioned to admit outside air for ventilation. The dampers then remain at minimum position until the economizer controller closes both its PV and DEV contacts. The economizer controller closes its PV contacts when the outside air temperature indicates that the building requires cooling rather than heating. The economizer controller closes its DEV contacts when the outside air temperature is sufficiently below the return air temperature to be effective for cooling. When both these contacts close, the dampers are modulated by mixed air temperature control.

(9) Mixed air temperature control. A mixed air temperature controller with its temperature transmitter in the mixed air modulates the outside air damper and relief air dampers between minimum position and fully open to maintain a mixed air temperature of 13 degrees C (55 degrees F). As the outside air and relief air dampers open, the return air damper closes.

(10) Cold duct temperature control. A cold duct temperature controller with its temperature transmitter in the cold duct discharge modulates the cooling coil valve to maintain its setpoint temperature, during the ventilation delay and occupied modes.

(11) Hot duct temperature control. A hot duct temperature controller with its temperature transmitter in the heating coil discharge modulates the heating coil valve to maintain its temperature setpoint. Another controller with a temperature transmitter in the outside air lowers the setpoint of the hot duct controller as outside air temperature rises. On a fall in outside air temperature the reverse occurs.

(12) Zone space temperature control. On a rise in temperature, each zone thermostat modulates the zone dual-duct box damper actuator to maintain its setpoint.

(13) Unoccupied mode of operation. Throughout the unoccupied mode, the outside air and relief air dampers and the cooling coil valve remain closed, and the return air damper remains open. The supply and return fans are cycled by the system's night thermostat to maintain its low limit space temperature setpoint.

(14) Ventilation delay mode of operation. During the ventilation delay mode, the dampers remain as they were throughout the unoccupied mode, and the supply and return fans run continuously. Until the ventilation delay mode ends, the HVAC system circulates return air to bring the building to comfort conditions, using a minimum of energy.

(15) Occupied mode of operation. The supply and return fans run continuously, and the outside air and relief air dampers are at minimum position or are under mixed air temperature control as previously described.

c. Detailed sequence of operation.

(1) Time clock CLK-XX-01 has two independent sets of contacts, which between them determine the mode of system operation. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-04 and lighting pilot light PL-XX-02. The normally closed contacts of relay R-XX-04 open, preventing relay R-XX-03 from being energized. The normally open contacts of relay R-XX-03 prevent any signal from reaching current-to-pneumatic transducer IP-XX-01. Thus, the dampers remain in their normal positions, with outdoor air and relief air dampers closed and return air damper open.

(2) When the timeclock's occupied contacts close, relays R-XX-01 and R-XX-02 are energized and pilot light PL-XX-01 is turned on. The contacts of relay R-XX-02 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-05, energizing the return fan, and, with the contacts of relay R-XX-01, energize relay R-XX-06. The contacts of relay R-XX-06 put the cold duct temperature controller in control of cooling coil valve VLV-XX-01. The outside air and relief air dampers remain closed and the return air damper remains open.

(3) When the ventilation delay contacts of time clock CLK-XX-01 open to end the ventilation delay mode of operation, relay R-XX-04 is de-energized and pilot light PL-XX-02 is turned off. The normally closed contacts of relay R-XX-04, in series with the now closed but normally open contacts of relays R-XX-01 and R-XX-05, energize relay R-XX-03. The normally open contacts of relay R-XX-03 connect the output signal of high signal selector TY-XX-01 to current-to-pneumatic transducer IP-XX-01. The pneumatic output of transducer IP-XX-01 places the dampers at the minimum position set on minimum position switch MPS-XX-01, unless relay R-XX-07 is energized. Economizer EC-XX-01 controls the action of relay R-XX-07. The economizer receives signals from outside air temperature transmitter TT-XX-02 and from return air transmitter TT-XX-03. The difference between the return air temperature and the outside air temperature controls the DEV contacts, and the outside air temperature controls the PV contacts. When both these contacts are closed, relay R-XX-07 is energized and pilot light PL-XX-03 is turned on. When relay R-XX-07 is energized, its contacts connect the output of mixed air controller TC-XX-01 to high signal selector TY-XX-01 to modulate the outside air and return air dampers between minimum position and fully open, while modulating the return air damper in the opposite direction to maintain the mixed air temperature controller setpoint.

(4) On a fall in temperature to its setpoint, low temperature protection thermostat TSL-XX-01 opens a set of closed contacts in the supply fan circuit, de-energizing the supply fan. The auxiliary contacts of the supply fan starter de-energize relay R-XX-05, and the contacts of relay R-XX-05 in the return fan starter circuit de-energize the return fan. A set of open contacts in low temperature protection thermostat TSL-XX-01 close, energizing relay R-XX-08 and lighting pilot light PL-XX-05. The contacts of relay R-XX-08 energize relays R-XX-10 and R-XX-11. One set of the contacts of relay R-XX-10 locks in relays R-XX-10 and R-XX-11, and another set de-energizes the supply fan. The contacts of relay R-XX-11 de-energize the return fan. To restart the fans after a low temperature shutdown, both the low temperature thermostat TSL-XX-01 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-02.

(5) When smoke detector SMK-XX-01 or smoke detector SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan starter circuit open, de-energizing the supply fan. The auxiliary contacts of the supply fan starter de-energize relay R-XX-05, and the contacts of relay R-XX-05 in the return fan starter circuit de-energize the return fan. Its normally open contacts close, energizing relay R-XX-09. The normally open contacts of R-XX-09 close, energizing relays R-XX-10 and R-XX-11. One set of contacts of relay R-XX-10 locks in relays R-XX-10 and R-XX-11. The other set of the contacts of relay R-XX-10 de-energizes the supply fan, and the contacts of relay R-XX-11 de-energize the return fan. To restart the fans after a smoke alarm shutdown, smoke detectors SMK-XX-01 and/or SMK-XX-02 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-02.

(6) Differential pressure gauge DPI-XX-01 across the filter gives local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-01 turns on filter pilot light PL-XX-04.

(7) Temperature transmitter TT-XX-04 signals the cold duct discharge temperature to temperature controller TC-XX-02. During the ventilation delay and occupied modes, relay R-XX-06 is energized and its contacts close, allowing the TC-XX-02 signal to be received by current-to-pneumatic transducer IP-XX-02. The pneumatic output of IP-XX-02 modulates cooling coil valve VLV-XX-01 to maintain the setpoint of controller TC-XX-02. During the unoccupied mode, the contacts of relay R-XX-06 are open, cooling coil valve control is interrupted, and the valve closes.

(8) Hot duct temperature controller TC-XX-03, with its temperature transmitter TT-XX-05 in the heating coil discharge, modulates hot duct heating coil valve VLV-XX-02 to maintain its temperature setpoint. Controller TC-XX-04, with its temperature transmitter TT-XX-02 in the outside air, raises the setpoint of controller TC-XX-03 on a fall in outside air temperature, and lowers it on a rise in outside air temperature.

(9) On a rising space temperature, thermostat T-XX-XX modulates dual-duct box actuator DA-XX-XX to gradually close the box to the hot duct and gradually open it to the cold duct.

(10) When the occupied contacts of time clock CLK-XX-01 open to end the occupied mode and index the system to the unoccupied mode, relays R-XX-01 and R-XX-02 are de-energized and pilot light PL-XX-01 is turned off. The contacts of relay R-XX-02 open, de-energizing the supply fan and placing the system's night thermostat TSL-XX-02 in control of the supply fan, and, through interlock as previously described, in control of the return fan. On a fall in space temperature to 13 degrees C (55 degrees F), the contacts of TSL-XX-02 close, energizing both fans; on a rise in temperature to 16 degrees C (60 degrees F), the contacts open, de-energizing the fans.

d. Sequence of operation for DDC applications.

(1) Ventilation delay mode timing shall start prior to the occupied mode timing. During ventilation delay mode the dampers shall remain in their normal positions as shown, except when under economizer control. At the time shown, the DDC system shall place the system in the occupied mode. At the expiration of the ventilation delay mode timing period, the DDC system shall place the outside air, return air, and relief air dampers under mixed air temperature and economizer control. At the time shown, the DDC system shall place the control system in the unoccupied mode of operation and the dampers shall return to their normal positions as shown.

(2) During occupied and ventilation delay modes the supply fan and return fan shall operate continuously. During unoccupied mode the supply fan and the return fan shall cycle according to the night setback schedule. The fans shall start and stop at the setpoints as shown.

(3) A differential pressure switch across the filter shall initiate a filter alarm when the pressure drop across the filter exceeds the setpoint as shown.

(4) A freezestat, located as shown, shall stop the supply and return fans, cause the outside air, return air, and relief air dampers to return to their normal position, and shall initiate a low temperature alarm if the temperature drops below the freezestat's setpoint. Return to the normal mode of operation shall require manual reset at the freezestat. The DDC panel shall monitor the freezestat through auxiliary contacts and shall indicate an alarm condition when the freezestat trips.

(5) Smoke Detectors in the supply air and return air ductwork shall stop the supply fan and the return fan and initiate a smoke alarm if smoke is detected at either location. Restarting the fans shall require manual reset at the smoke detector.

(6) The DDC system shall modulate the heating coil control valve from the signal of a temperature sensing element and transmitter located in the discharge air of the coil to maintain the hot duct temperature setpoint. A temperature sensing element and transmitter in the outside air intake shall reset the hot duct temperature setpoint with respect to the outside air temperature signal in a linear schedule as shown.

(7) During occupied and ventilation delay modes, the cooling coil control valve shall be modulated by the DDC system from the signal of a temperature sensing element and transmitter located in the coil discharge air to maintain the cold duct temperature setpoint as shown. During the unoccupied mode, the cooling coil control valve shall remain closed.

(8) The DDC system shall accept the signal of an outside air temperature sensing element and transmitter and the signal of a return air temperature sensing element and transmitter. The DDC system shall perform switch over between outside air economizer control mode and minimum outside air mode. Until the outside air temperature rises above the setpoint, the DDC system shall hold the system in the minimum outside air mode. When the outside air temperature rises above the setpoint, the DDC system shall place the AHU in the economizer mode or in the minimum outside air mode as determined by a comparison of the outside air and return air temperatures in accordance with the differential temperature setpoints as shown. When the outside air temperature is low with respect to the return air temperature, the AHU shall be in the economizer mode. When the DDC system places the control system in the minimum outside air mode, the outside air damper shall be open to the minimum outdoor air setting.

When the DDC system places the system in the economizer mode, it shall modulate the dampers from the signal of a temperature sensing element and transmitter in the mixed air stream to maintain the setpoint as shown.

(9) A space temperature sensor for each zone shall signal the DDC system to gradually operate the control dampers of the dual-duct box to heat and cool its respective zone by mixing cold duct air and hot duct air to maintain the setpoint. On a rise in space temperature, the hot duct damper shall gradually close, and the cold duct damper shall gradually open.

20. BYPASS MULTIZONE HVAC CONTROL SYSTEM WITH RETURN FAN.

a. Description of the HVAC system. This is an air handling system with supply and return fans, economizer dampers, a cold deck with a cooling coil, a bypass deck, individual zone mixing dampers, and individual zone heating controls. Figures 4-16a through 4-16f show the control system design for this type of air handling system using a SLDC control panel. Figures 4-16g through 4-16j show the control system design for this type of air handling system using DDC controls. Since this system provides for a deadband between heating and cooling, the use of an economizer cycle does not have the problems associated with the previous two systems. A more detailed discussion is presented in chapter three.

Figure 4-16a. Control system schematic for bypass multizone HVAC system.

Figure 4-16b. Control system ladder diagram for bypass multizone HVAC system.

Figure 4-16c. Control system equipment for bypass multizone HVAC system.

Figure 4-16d. Control panel interior door layout for bypass multizone HVAC system.

Figure 4-16e. Control panel back panel layout for bypass multizone HVAC system.

Figure 4-16f. Control panel terminal block layout for bypass multizone HVAC system.

Figure 4-16g. DDC control system schematic for bypass multizone HVAC system.

Figure 4-16h. DDC control system ladder diagram for bypass multizone HVAC system.

Figure 4-16i. DDC control system equipment for bypass multizone HVAC system.

Figure 4-16j. DDC control system I/O table and data terminal strip layout for bypass multizone HVAC system.

b. General sequence of operation.

(1) Supply air and return air fans off. When the fans are off, the cooling coil valve, the outside air and relief air dampers are closed. The return air damper is open. Zone heating coil valves and dampers are under the control of their zone thermostats.

(2) Supply air and return air fans operating. When the fans are on, the control dampers and the cooling coil valve are operated as required by the system's mode of operation. Zone heating coil valves and dampers are under the control of their zone thermostats. The control dampers are either positioned for full recirculation of air, positioned to introduce minimum outside air, or modulated to maintain mixed air temperature. The cooling coil valve is either closed, or modulated to maintain cold deck temperature.

(3) Control of supply air and return air fans. Unless the fans are stopped as the result of a safety shutdown, they are on or off as required by the control system's mode of operation.

(4) Safety shutdown of the fans. The control system shuts down the fans if there is a low temperature condition, or if smoke is detected.

(5) Low temperature detection. On a fall in temperature to its setpoint, a low temperature protection thermostat stops the supply air and return air fans. To restart the fans, the thermostat and the control panel must be manually reset.

(6) Smoke detection. Duct smoke detectors stop the supply air and return air fans whenever either detects the presence of smoke. To restart the fans, the smoke detectors and control panel must be manually reset.

(7) Filter condition. Filter condition is monitored by a pressure gauge and a differential pressure switch. On a rise in pressure drop across the filter to the switch setpoint, the switch turns on a pilot light.

(8) Economizer control. When the control system modes of operation no longer require the outside air, return air, and relief air dampers to be in their full recirculation positions, the dampers are positioned to admit outside air for ventilation. The dampers then remain at minimum position until the economizer controller closes both its PV and DEV contacts. The economizer controller closes its PV contacts when the return air temperature indicates that the building requires cooling rather than heating. The economizer controller closes its DEV contacts when the outside air temperature is sufficiently below the return air temperature to be effective for cooling. When both these contacts close, the dampers are modulated by mixed air temperature control.

(9) Mixed air temperature control. A mixed air temperature controller with its temperature transmitter in the mixed air modulates the outside air and relief air dampers between minimum position and fully open, to maintain a mixed air temperature of 13 degrees C (55 degrees F). As the outside air and relief air dampers open, the return air damper closes.

(10) Cold deck temperature control. A cold deck temperature controller with its temperature transmitter in the cold deck discharge modulates the cooling coil valve to maintain its setpoint temperature. During the unoccupied mode, the cooling coil valve is not controlled and remains closed.

(11) Space temperature control. On a rise in temperature, each zone thermostat first modulates its zone reheat coil valve toward closed. On a further rise in temperature after a space temperature deadband, each zone thermostat modulates its cold deck damper toward open and simultaneously modulates its bypass damper toward closed.

(12) Unoccupied mode of operation. Throughout the unoccupied mode, the outside air and relief air dampers and the cooling coil valve remain closed, and the return air damper remains open. The supply and return fans are cycled by the system's night thermostat to maintain its low limit space temperature setpoint.

(13) Ventilation delay mode of operation. During the ventilation delay mode, the dampers remain as they were throughout the unoccupied mode, and the supply air and return air fans run continuously. Until the ventilation delay mode ends, return air is circulated, to bring the building to comfort conditions using a minimum of energy.

(14) Occupied mode of operation. The supply air and return air fans run continuously, and the outside air and relief air dampers are at minimum position or are under mixed air temperature control as previously described.

c. Detailed sequence of operation.

(1) Time clock CLK-XX-01 has two independent sets of contacts, which between them determine the mode under which the system operates. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-04 and lighting pilot light PL-XX-02. The normally closed contacts of relay R-XX-04 open, preventing relay R-XX-03 from being energized. The normally open contacts of relay R-XX-03 prevent any signal reaching current-to-pneumatic transducer IP-XX-01. Thus, the dampers remain in their normal positions with outside air and relief air dampers closed and return air damper open.

(2) When the timeclock's occupied contacts close, relays R-XX-01 and R-XX-02 are energized and pilot light PL-XX-01 is turned on. The contacts of relay R-XX-02 energize the supply fan. The auxiliary contacts of the supply fan energize relay R-XX-05 and, with contacts of relay R-XX-01, energize relay R-XX-06. The contacts of relay R-XX-06 places the cold deck temperature controller in control of cooling coil valve VLV-XX-01. The outside air and relief air dampers remain closed and the return air damper remains open.

(3) When the ventilation delay contacts of time clock CLK-XX-01 open to end the ventilation delay mode of operation, relay R-XX-04 is de-energized and pilot light PL-XX-02 is turned off. The normally closed contacts of relay R-XX-04, in series with the now closed but normally open contacts of relays R-XX-01 and R-XX-05, energize relay R-XX-03. The normally open contacts of relay R-XX-03 connect the output signal of high signal selector TY-XX-01 to current-to-pneumatic transducer IP-XX-01. The pneumatic output of transducer IP-XX-01 places the dampers at the minimum position set on minimum position switch MPS-XX-01, unless relay R-XX-07 energized. Economizer EC-XX-01 controls the action of relay R-XX-07. The economizer receives signals from outside air temperature transmitter TT-XX-02 and from return air transmitter TT-XX-03. The difference between the return air temperature and the outside air temperature controls the DEV contacts, and the return air temperature controls the PV contacts. When both these contacts are closed, relay R-XX-07 is energized and pilot light PL-XX-03 is turned on. When relay R-XX-07 is energized, its contacts connect the output of mixed air controller TC-XX-01 to high signal selector TY-XX-01 to modulate the outside air and return air dampers between minimum position and fully open while modulating the return air damper in the opposite direction to maintain the temperature controller setpoint.

(4) On a fall in temperature to its setpoint, low temperature protection thermostat TSL-XX-01 opens a set of closed contacts in the supply fan circuit, de-energizing the supply fan. The auxiliary contacts of the supply fan starter de-energize relay R-XX-05, and the contacts of relay R-XX-05 in the return fan starter circuit de-energize the return fan. A set of open contacts in low temperature protection thermostat TSL-XX-01 close, energizing relay R-XX-08 and lighting pilot light PL-XX-05. The contacts of relay R-XX-08 energize relays R-XX-10 and R-XX-11. One set of the contacts of relay R-XX-10 locks in relays R-XX-10 and R-XX-11, and another set de-energizes the supply fan. The contacts of relay R-XX-11 de-energize the return fan. To restart the fans after a low temperature shutdown, both the low

temperature thermostat TSL-XX-01 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-02.

(5) When smoke detector SMK-XX-01 or smoke detector SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan starter circuit open, de-energizing the supply fan. The auxiliary contacts of the supply fan starter de-energize relay R-XX-05, and the contacts of relay R-XX-05 in the return fan starter circuit de-energize the return fan. Its normally open contacts close, energizing relay R-XX-09. The normally open contacts of R-XX-09 close, energizing relays R-XX-10 and R-XX-11. One set of the contacts of relay R-XX-10 locks in relays R-XX-10 and R-XX-11; the other set de-energizes the supply fan. The contacts of relay R-XX-11 de-energize the return fan. To restart the fans after a smoke alarm shutdown, smoke detectors SMK-XX-01 and/or SMK-XX-02 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-02.

(6) A differential pressure gauge DPI-XX-01 across the filter gives local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-01 turns on pilot light PL-XX-04.

(7) Temperature transmitter TT-XX-04 signals the cold deck discharge temperature to temperature controller TC-XX-02. During the ventilation delay and occupied modes, relay R-XX-06 is energized and its contacts close, allowing the TC-XX-02 signal to be received by current-to-pneumatic transducer IP-XX-02. The pneumatic output of IP-XX-02 modulates cooling coil valve VLV-XX-01 to maintain the setpoint of controller TC-XX-02. During the unoccupied mode, R-XX-06 is de-energized, cooling coil valve control is interrupted, and the valve closes.

(8) On a rising space temperature, thermostat T-XX-XX first modulates reheat coil valve VLV-XX-XX closed, through the auxiliary actuator driver (AAD) of damper actuator DA-XX-XX, and on a further temperature rise modulates DA-XX-XX to close the zone damper to the bypass duct and open it to the cold duct.

(9) When the occupied contacts of time clock CLK-XX-01 open to end the occupied mode and index the system to the unoccupied mode, relays R-XX-01 and R-XX-02 are de-energized, and pilot light PL-XX-01 is turned off. The contacts of relay R-XX-02 open, de-energizing the supply fan and placing the system's night thermostat TSL-XX-02 in control of the supply fan and, through interlock, in control of the return fan. On a fall in space temperature to 13 degrees C (55 degrees F), the contacts of TSL-XX-02 close, energizing both fans; on a rise in temperature to 16 degrees C (60 degrees F), the contacts open, de-energizing the fans.

d. Sequence of operation for DDC applications.

(1) Ventilation delay mode timing shall start prior to the occupied mode timing. During ventilation delay mode the dampers shall remain in their normal positions as shown, except when under economizer control. At the time shown, the DDC system shall place the system in the occupied mode. At the expiration of the ventilation delay mode timing period, the DDC system shall place the outside air, return air, and relief air dampers under mixed air temperature and economizer control. At the time shown, the DDC system shall place the control system in the unoccupied mode of operation and the dampers shall return to their normal positions as shown.

(2) During occupied and ventilation delay modes the supply fan and return fan shall operate continuously. During unoccupied mode the supply fan and the return fan shall cycle according to the night setback schedule. The fans shall start and stop at the setpoints as shown.

(3) A differential pressure switch across the filter shall initiate a filter alarm when the pressure drop across the filter exceeds the setpoint as shown.

(4) A freezestat, located as shown, shall stop the supply and return fans, cause the outside air, return air, and relief air dampers to return to their normal position, and shall initiate a low temperature alarm if the temperature drops below the freezestat's setpoint. Return to the normal mode of operation shall require manual reset at the freezestat. The DDC panel shall monitor the freezestat through auxiliary contacts and shall indicate an alarm condition when the freezestat trips.

(5) Smoke Detectors in the supply air and return air ductwork shall stop the supply fan and the return fan and initiate a smoke alarm if smoke is detected at either location. Restarting the fans shall require manual reset at the smoke detector.

(6) During occupied and ventilation delay modes, the cooling coil control valve shall be modulated by the DDC system from the signal of a temperature sensing element and transmitter located in the coil discharge air to maintain the cold duct temperature setpoint as shown. During the unoccupied mode, the cooling coil control valve shall remain closed.

(7) The DDC system shall accept the signal of an outside air temperature sensing element and transmitter and the signal of a return air temperature sensing element and transmitter. The DDC system shall perform switch over between outside air economizer control mode and minimum outside air mode. Until the return air temperature rises above the setpoint, the DDC system shall hold the system in the minimum outside air mode. When the return air temperature rises above the setpoint, the DDC system shall place the AHU in the economizer mode or in the minimum outside air mode as determined by a comparison of the outside air and return air temperatures in accordance with the differential temperature setpoints as shown. When the outside air temperature is low with respect to the return air temperature, the AHU shall be in the economizer mode. When the DDC system places the control system in the minimum outside air mode, the outside air damper shall be open to the minimum outdoor air setting. When the DDC system places the system in the economizer mode, it shall modulate the dampers from the signal of a temperature sensing element and transmitter in the mixed air stream to maintain the setpoint as shown.

(8) A space temperature sensor for each zone shall signal the DDC system to gradually operate the zone mixing damper and heating coil to heat and cool its respective zone by mixing cold deck air and bypass deck air to maintain the setpoint. On a rise in space temperature, the heating coil valve shall gradually close, and after a deadband as shown, the bypass deck damper shall gradually close and the cold deck damper shall gradually open.

21. VARIABLE AIR VOLUME (VAV) HVAC CONTROL SYSTEM WITHOUT RETURN FAN.

a. Description of the HVAC system. This is an air handling system with an inlet vane equipped supply fan, economizer dampers, filters, and cooling coil. Variable air volume (VAV) boxes, some of which have heating coils, are located downstream in the ductwork near the areas served by the system. Figures 4-17a through 4-17f show the control system design for this type of air handling system using a SLDC control panel. Figures 4-17g through 4-17j show the control system design for this type of air handling system using DDC controls.

Figure 4-17a. Control system schematic for VAV HVAC system without return fan.

Figure 4-17b. Control system ladder diagram for VAV HVAC system without return fan.

Figure 4-17c. Control system equipment for VAV HVAC system without return fan.

Figure 4-17d. Control panel interior door layout for VAV HVAC system without return fan.

Figure 4-17e. Control panel back panel layout for VAV HVAC system without return fan.

Figure 4-17f. Control panel terminal block layout for VAV HVAC system without return fan.

Figure 4-17g. DDC control system schematic for VAV HVAC system without return fan.

Figure 4-17h. DDC control system ladder diagram for VAV HVAC system without return fan.

Figure 4-17i. DDC control system equipment for VAV HVAC system without return fan.

Figure 4-17j. DDC control system I/O table and data terminal strip layout for VAV HVAC system without return fan.

b. General sequence of operation.

(1) Supply fan off. When the fan is off, the cooling coil valve and the outside air, relief air, and supply fan inlet vane dampers are closed. The return air damper is open.

(2) Supply fan operating. When the supply fan is on, the cooling coil valve and the control dampers are operated as required by the system's mode of operation. The control dampers are either positioned for full recirculation of air, positioned to introduce minimum outside air, or modulated to maintain the mixed air temperature. The cooling coil valve is either closed, or modulated to maintain unit discharge temperature.

(3) Control of supply fan. Unless the fan is stopped as the result of a safety shutdown, it is on or off as required by the control system's mode of operation. When the fan is on, the inlet vanes are modulated to maintain the required supply air static pressure.

(4) Safety shutdown of the fan. The control system shuts down the fan if there is a low temperature condition, if smoke is detected, or if a high static pressure condition is detected.

(5) Low temperature detection. On a fall in temperature to its setpoint, a freezestat stops the supply fan. To restart the fan, the freezestat and the control panel must be manually reset.

(6) Smoke detection. Duct smoke detectors stop the supply fan whenever either detects the presence of smoke. To restart the fan, the smoke detectors and the control panel must be manually reset.

(7) High static pressure detection. On a rise in static pressure above the setpoint of a high limit static pressure switch downstream of the supply fan, the fan stops. To restart the fan, the control panel must be manually reset.

(8) Filter condition. Filter conditions are monitored by a pressure gauge and a differential pressure switch. When the pressure drop across the filter exceeds the switch setpoint, the switch turns on a pilot light.

(9) Minimum Outside Air Flow Control. A minimum outside air flow controller accepts a signal from a outside air flow station transmitter. When the fan is on, with the control system in the occupied mode, and with the ventilation delay mode off, the outside air flow controller modulates the minimum outside air damper to maintain the control setpoint.

(10) Economizer control. The economizer controller closes its PV contacts when the return air temperature indicates that the building requires cooling rather than heating. The economizer controller closes its DEV contacts when the outside air temperature is sufficiently below the return air temperature to be effective for cooling. When both these contacts close, the dampers are modulated by the mixed air temperature controller.

(11) Mixed air temperature control. A mixed air temperature controller, with its temperature transmitter in the mixed air, modulates the economizer outside air damper, relief air damper, and the return air damper to maintain a mixed air temperature of 13 degrees C (55 degrees F). As the economizer outside air and relief air dampers open, the return air damper closes.

(12) Cooling coil temperature control. During the ventilation delay and occupied modes, a cooling coil temperature controller, with its temperature transmitter in the unit discharge air, modulates the cooling coil valve to maintain its setpoint temperature. During the unoccupied mode, the cooling coil valve is not controlled and remains closed.

(13) Space temperature control. Each controlled space is equipped with a variable air volume (VAV) box, which is controlled by a microprocessor based VAV box controller. The controller receives temperature signals from a temperature sensing element in the space served and from a flow sensor upstream of the VAV box. On a fall in space temperature, the controller modulates the damper toward minimum position, to maintain the cooling mode setpoint. After the minimum position is reached, the controller is inactive while the space temperature falls through a temperature deadband. On a further fall in temperature below the temperature deadband, the heating coil valve modulates to maintain the heating setpoint.

(14) Unoccupied mode of operation. Throughout the unoccupied mode, the outside air and relief air dampers and the cooling coil valve remain closed, and the return air damper remains open. The supply fan is cycled by the system's night thermostat to maintain its low limit space temperature setpoint.

(15) Ventilation delay mode of operation. During the ventilation delay mode, the dampers remain as they were throughout the unoccupied mode, and the supply fan runs continuously. Until the ventilation delay mode ends, return air is recirculated, to bring the building to comfort conditions using a minimum of energy.

(16) Occupied mode of operation. The supply fan runs continuously, the minimum outside air damper is modulated to maintain minimum outside air flow, and the economizer outside air and relief air dampers are either closed or are under mixed air temperature control as previously described.

c. Detailed sequence of operation.

(1) Timeclock CLK-XX-01 has two independent sets of contacts, which between them determine the mode of system operation. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-04 and lighting pilot light PL-XX-02. The normally closed contacts of relay R-XX-04 open, preventing relay R-XX-03 from being energized. The normally open contacts of relay R-XX-03 prevent any signal from reaching current-to-pneumatic transducers IP-XX-01 and IP-XX-04. Thus, the dampers remain in their normal positions, with outside air and relief air dampers closed and return air damper open.

(2) When the timeclock's occupied contacts close, relays R-XX-01 and R-XX-02 are energized and pilot light PL-XX-01 is turned on. The contacts of relay R-XX-02 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-05 and relay R-XX-07, and, with the contacts of relay R-XX-01, energize relay R-XX-06. The contacts of relay R-XX-05 are involved in the energizing of relay R-XX-03 when the ventilation delay mode of operation is over. The contacts of relay R-XX-06 enable discharge temperature controller TC-XX-02 to control cooling coil valve VLV-XX-01. The contacts of relay R-XX-07 enable control of the inlet guide vanes on the supply fan. The outside air and relief air dampers remain closed and the return air damper remains open.

(3) When the ventilation delay contacts of timeclock CLK-XX-01 open to end the ventilation delay mode of operation, relay R-XX-04 is de-energized and pilot light PL-XX-01 is turned off. The normally closed contacts of relay R-XX-04, in series with the now closed but normally open contacts of relays R-XX-01 and R-XX-05, energize relay R-XX-03. One pair of normally open contacts of relay R-XX-03 connect the output of the minimum outside air flow controller FC-XX-01 to current-to-pneumatic transducer IP-XX-04, allowing modulation of the minimum outside air damper to maintain the flow at setpoint. The other pair of normally open contacts of relay R-XX-03 connect the output signal of the mixed air temperature controller TC-XX-01 to current-to-pneumatic transducer IP-XX-01, if the normally open contacts of relay R-XX-08 are also closed. Economizer EC-XX-01 controls the action of relay R-XX-08. The economizer receives signals from outside air temperature transmitter TT-XX-02 and from return air transmitter TT-XX-03. The difference between the return air temperature and the outside air temperature controls the DEV contacts, and the return air temperature controls the PV contacts. When both these contacts are closed, relay R-XX-08 is energized and pilot light PL-XX-03 is turned on. When relays R-XX-03 and R-XX-08 are both energized, the output of mixed air controller TC-XX-01 is received by current-to-pneumatic transducer IP-XX-01 and the economizer outside air, relief air, and return air dampers are modulated to maintain the mixed air temperature controller setpoint.

(4) On a fall in temperature to its setpoint, low temperature protection thermostat TSL-XX-01 opens a set of closed contacts in the supply fan circuit, de-energizing the supply fan. A set of normally open contacts in low temperature protection thermostat TSL-XX-01 close, energizing relay R-XX-09 and lighting pilot light PL-XX-05. The contacts of relay R-XX-09 energize relay R-XX-12. One set of the contacts of relay R-XX-12 locks in relay R-XX-12, and another set de-energizes the supply fan. To restart the fan after a low temperature shutdown, both low temperature thermostat TSL-XX01 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-03.

(5) When either smoke detector SMK-XX-01 or smoke detector SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan starter circuit open, de-energizing the supply fan. Its normally open contacts close, energizing relay R-XX-10 and turning on pilot light PL-XX-06. The normally open contacts of R-XX-10 close, energizing relay R-XX-12. One set of contacts of relay R-XX-12 locks in relay R-XX-12. The other set of contacts of relay R-XX-12 de-energizes the

supply fan. To restart the fans after a smoke alarm shutdown, smoke detectors SMK-XX-01 and/or SMK-XX-02 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-03.

(6) Differential pressure gauge DPI-XX-01 across the filter provides local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-01 turns on filter pilot light PL-XX-04.

(7) Differential pressure gauge DPI-XX-03 across the outside air filter provides local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-03 turns on filter pilot light PL-XX-08.

(8) Temperature controller TC-XX-02, with its temperature transmitter TT-XX-04 in the unit discharge, through the contacts of relay R-XX-06 and current-to-pneumatic transducer IP-XX-02 modulates cooling coil valve VLV-XX-01 to maintain its temperature setpoint. The contacts of relay R-XX-06 are closed during the ventilation delay and occupied modes, allowing control. The contacts are open during the unoccupied mode, the cooling coil valve control signal is interrupted, and the valve remains closed.

(9) A pressure sensing element and transmitter DPT-XX-01 located in the supply duct (the location is determined by field conditions) signals duct static pressure to controller PC-XX-01. Whenever the supply fan runs, the auxiliary contacts of the fan starter energize relay R-XX-07. The output of pressure controller PC-XX-01 is sent, through the contacts of relay R-XX-07, to current-to-pneumatic transducer IP-XX-03. The pneumatic output of the transducer modulates the supply fan inlet vane actuator DA-XX-04 to maintain the pressure controller setpoint. When the fan is de-energized, relay R-XX-07 is de-energized, its contacts open, and the inlet vane dampers remain closed.

(10) When the setpoint of high limit static pressure switch DPS-XX-02 in the supply fan discharge is exceeded, its contacts close, energizing relay R-XX-11 and lighting high-static pilot light PL-XX-07. One set of the contacts of relay R-XX-11 locks in relay R-XX-11, and another set of contacts energizes relay R-XX-12. One set of the contacts of relay R-XX-12 locks in relay R-XX-12, and the other set of contacts de-energizes the supply fan. To restart the fan, manual switch HS-XX-02 must be momentarily depressed and then manual switch HS-XX-03 must be depressed.

(11) Temperature sensing element TE-XX-XX and air flow sensing element FE-XX-XX signal the VAV box controller to modulate reheat coil valve VLV-XX-XX and VAV box damper actuator DA-XX-XX. On a rising space temperature, the VAV box controller first gradually closes VLV-XX-XX and then, after the space temperature passes through a dead band, gradually opens the VAV box beyond minimum air flow position to maximum air flow position to maintain setpoint.

(12) When the occupied contacts of timeclock TC-XX-01 open to end the occupied mode and index the system to the unoccupied mode, relays R-XX-01 and R-XX-02 are de-energized and pilot light PL-XX-01 is turned off. The contacts of relay R-XX-02 open, de-energizing the supply fan and placing the system's night thermostat TSL-XX-02 in control of the supply fan. On a fall in space temperature to 13 degrees C (55 degrees F), the contacts of TSL-XX-02 close, energizing the supply fan; on a rise in temperature to 16 degrees C (60 degrees F), the contacts open, de-energizing the fan.

d. Sequence of operation for DDC applications

(1) Ventilation delay mode timing shall start prior to the occupied mode timing. During ventilation delay mode, the dampers shall remain in their normal positions as shown, except when under economizer control. At the time shown, the DDC system shall place the system in the occupied mode. At the expiration of the ventilation delay mode timing period, the DDC system shall place the minimum outside air damper under minimum outside air flow control and shall place the economizer outside air, return air, and relief air dampers under mixed air temperature and economizer control. At the time shown, the DDC system shall place the control system in the unoccupied mode of operation and all dampers shall return to their normal positions as shown.

(2) During occupied and ventilation delay modes the supply fan shall operate continuously. During unoccupied mode the supply fan shall cycle according to the night setback schedule. The fan shall start and stop at the setpoints as shown.

(3) When the supply fan starts, the DDC system shall modulate the inlet vanes from the signal of a static pressure sensing element and transmitter to maintain the setpoint as shown. A high limit static pressure switch in the fan discharge shall stop the supply fan and initiate a high static alarm when the static pressure exceeds the setpoint. When the fan is off, the inlet vanes shall be closed.

(4) A differential pressure switch across each filter shall initiate a filter alarm when the pressure drop across the filter reaches the setpoint as shown.

(5) A freezestat, located as shown, shall stop the supply fan, cause the outside air, return air, and relief air dampers to return to their normal position, and shall initiate a low temperature alarm if the temperature drops below the freezestat's setpoint as shown. The DDC system shall monitor the freezestat through auxiliary contacts and shall indicate an alarm condition when the freezestat trips.

(6) Smoke detectors in the supply air and return air ductwork shall stop the supply fan and initiate a smoke alarm if smoke is detected at either location. Restarting the supply fan shall require manual reset at the smoke detector.

(7) During occupied and ventilation delay modes, the cooling coil control valve shall be modulated by the DDC system from the signal of a temperature sensing element and transmitter located in the coil discharge air to maintain the setpoint as shown. During unoccupied mode, cooling coil control valve shall remain closed.

(8) Minimum Outside Air Flow Control. When the fan is on, with the control system in the occupied mode, and with the ventilation delay mode off, the minimum outside air damper shall be modulated to maintain the minimum outside air flow at setpoint, as sensed by an air flow measurement station located in the minimum outside air duct.

(9) The DDC system shall accept the signal of an outside air temperature sensing element and transmitter and the signal of a return air temperature sensing element and transmitter. When the return air temperature is above the economizer setpoint, and the outside air temperature is sufficiently below the return air temperature to be effective for cooling, the DDC system shall place the AHU in the economizer mode by modulating the economizer outside air, relief air, and the return air dampers to maintain the mixed air temperature at setpoint. As the economizer outside air and relief air dampers open, the return air damper closes. When the system is not in economizer mode, the economizer outside air and relief air dampers shall remain closed and the return air damper shall remain open.

(10) The control damper of the VAV box shall modulate in response to the signal from a flow sensing element at the discharge or inlet of the VAV box to a microprocessor based VAV box velocity controller. The velocity controller shall control the box damper from the minimum flow position to the full flow position from the signal of a space temperature sensing element located as shown. When the space temperature decreases, the damper shall gradually close to the minimum flow position to maintain the cooling setpoint as shown. When the space temperature calls for heating after the minimum flow position is reached, control shall then pass through a temperature dead band as shown. When the space temperature has dropped through the dead band, the duct heater coil shall be gradually controlled to maintain the heating setpoint as shown.

22. VARIABLE AIR VOLUME (VAV) HVAC CONTROL SYSTEM WITH RETURN FAN.

a. Description of the HVAC system. This is an air handling system with inlet vane equipped supply and return fans, economizer dampers, filters, and cooling coil. Variable air volume (VAV) boxes, some of which have heating coils, are located downstream in the ductwork near the areas served by the system. Figures 4-18a through 4-18f show the control system design for this type of air handling system using a SLDC control panel. Figures 4-18g through 4-18j show the control system design for this type of air handling system using DDC controls. A variation of this system which uses variable speed drives instead of inlet guide vanes is shown in the following chapter. The return fan volume control loop is costly, complex, and, in some applications, difficult to control with stability. A return fan should be used in a VAV system only when absolutely necessary. The need for a return fan can be reduced by keeping return duct losses to a minimum using a plenum or making the return duct as short and as large as possible.

Figure 4-18a. Control system schematic for VAV HVAC system with return fan.

Figure 4-18b. Control system ladder diagram for VAV HVAC system with return fan.

Figure 4-18c. Control system equipment for VAV HVAC system with return fan.

Figure 4-18d. Control panel interior door layout for VAV HVAC system with return fan.

Figure 4-18e. Control panel back panel layout for VAV HVAC system with return fan.

Figure 4-18f. Control panel terminal block layout for VAV HVAC system with return fan.

Figure 4-18g. DDC control system schematic for VAV HVAC system with return fan.

Figure 4-18h. DDC control system ladder diagram for VAV HVAC system with return fan.

Figure 4-18i. DDC control system equipment for VAV HVAC system with return fan.

Figure 4-18j. DDC control system I/O table and data terminal strip layout for VAV HVAC system with return fan.

b. General sequence of operation.

(1) Supply and return fans off. When the fans are off, the cooling coil valve and the outside air, relief air, supply fan inlet vane, and return fan inlet vane dampers are closed. The return air damper is open.

(2) Supply and return fans operating. When the fans are on, the cooling coil valve and the control dampers are operated as required by the system's mode of operation. The control dampers are either positioned for full recirculation of air, positioned to introduce minimum outside air, or modulated to maintain mixed air temperature. The cooling coil valve is either closed, or modulated to maintain unit discharge temperature.

(3) Control of supply and return fans. Unless the fans are stopped as the result of a safety shutdown, they are on or off as required by the control system's mode of operation. When the fans are on, the inlet vanes are modulated to maintain the required supply air static pressure and return air flow.

(4) Safety shutdown of the fans. The control system shuts down the fans if there is a low temperature condition, if smoke is detected, or if a high static pressure condition is detected.

(5) Low temperature detection. On a fall in temperature to its setpoint, a freezestat stops the supply and return fans. To restart the fans, the freezestat and the control panel must be manually reset.

(6) Smoke detection. Duct smoke detectors stop the supply and return fans whenever either detects the presence of smoke. To restart the fans, the smoke detectors and the control panel must be manually reset.

(7) High static pressure detection. On a rise in static pressure above the setpoint of a high limit static pressure switch downstream of the supply fan, the fans stop. To restart the fans, the control panel must be manually reset.

(8) Filter condition. Filter conditions are monitored by a pressure gauge and a differential pressure switch. When the pressure drop across the filter exceeds the switch setpoint, the switch turns on a pilot light.

(9) Minimum Outside Air Flow Control. A minimum outside air flow controller accepts a signal from a outside air flow station transmitter. When the fans are on, with the control system in the occupied mode, and with the ventilation delay mode off, the outside air flow controller modulates the minimum outside air damper to maintain the control setpoint.

(10) Economizer control. The economizer controller closes its PV contacts when the return air temperature indicates that the building requires cooling rather than heating. The economizer controller closes its DEV contacts when the outside air temperature is sufficiently below the return air temperature to be effective for cooling. When both these contacts close, the dampers are modulated by the mixed air temperature controller.

(11) Mixed air temperature control. A mixed air temperature controller, with its temperature transmitter in the mixed air, modulates the economizer outside air damper, relief air damper, and the return air damper to maintain a mixed air temperature of 13 degrees C (55 degrees F). As the economizer outside air and relief air dampers open, the return air damper closes.

(12) Cooling coil temperature control. During the ventilation delay and occupied modes, a cooling coil temperature controller, with its temperature transmitter in the unit discharge air, modulates

the cooling coil valve to maintain its setpoint temperature. During the unoccupied mode, the cooling coil valve is not controlled and remains closed.

(13) Space temperature control. Each controlled space is equipped with a variable air volume (VAV) box, which is controlled by a microprocessor based VAV box controller. The controller receives temperature signals from a temperature sensing element in the space served and from a flow sensor upstream of the VAV box. On a fall in space temperature, the controller modulates the damper toward minimum position, to maintain the cooling mode setpoint. After the minimum position is reached, the controller is inactive while the space temperature falls through a temperature deadband. On a further fall in temperature below the temperature deadband, the heating coil valve modulates to maintain the heating setpoint.

(14) Unoccupied mode of operation. Throughout the unoccupied mode, the outside air and relief air dampers and the cooling coil valve remain closed, and the return air damper remains open. The supply and return fans are cycled in unison by the system's night thermostat to maintain its low limit space temperature setpoint.

(15) Ventilation delay mode of operation. During the ventilation delay mode, the dampers remain as they were throughout the unoccupied mode, and the supply and return fans run continuously. Until the ventilation delay mode ends, return air is recirculated, to bring the building to comfort conditions using a minimum of energy.

(16) Occupied mode of operation. The supply and return fans run continuously, the minimum outside air damper is modulated to maintain minimum outside air flow, and the economizer outside air and relief air dampers are either closed or are under mixed air temperature control as previously described.

c. Detailed sequence of operation.

(1) Timeclock CLK-XX-01 has two independent sets of contacts, which between them determine the mode of system operation. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-04 and lighting pilot light PL-XX-02. The normally closed contacts of relay R-XX-04 open, preventing relay R-XX-03 from being energized. The normally open contacts of relay R-XX-03 prevent any signal from reaching current-to-pneumatic transducers IP-XX-01 and IP-XX-05. Thus, the dampers remain in their normal positions, with outside air and relief air dampers closed and return air damper open.

(2) When the timeclock's occupied contacts close, relays R-XX-01 and R-XX-02 are energized and pilot light PL-XX-01 is turned on. The contacts of relay R-XX-02 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-05, and relay R-XX-07, and, with the contacts of relay R-XX-01, energize relay R-XX-06. One set of contacts of relay R-XX-05 energizes the return fan. The other set of contacts (line 4) is involved in the energizing of relay R-XX-03 when the ventilation delay mode of operation is over. The contacts of relay R-XX-06 enable discharge temperature controller TC-XX-02 to control cooling coil valve VLV-XX-01. The contacts of relay R-XX-07 enable control of the inlet guide vanes on the supply and return fans. The outside air and relief air dampers remain closed and the return air damper remains open.

(3) When the ventilation delay contacts of timeclock CLK-XX-01 open to end the ventilation delay mode of operation, relay R-XX-04 is de-energized and pilot light PL-XX-01 is turned off. The normally closed contacts of relay R-XX-04, in series with the now closed but normally open contacts of

relays R-XX-01 and R-XX-05, energize relay R-XX-03. One pair of normally open contacts of relay R-XX-03 connect the output of the minimum outside air flow controller FC-XX-02 to current-to-pneumatic transducer IP-XX-05, allowing modulation of the minimum outside air damper to maintain the flow at setpoint. The other pair of normally open contacts of relay R-XX-03 connect the output signal of the mixed air temperature controller TC-XX-01 to current-to-pneumatic transducer IP-XX-01, if the normally open contacts of relay R-XX-08 are also closed. Economizer EC-XX-01 controls the action of relay R-XX-08. The economizer receives signals from outside air temperature transmitter TT-XX-02 and from return air transmitter TT-XX-03. The difference between the return air temperature and the outside air temperature controls the DEV contacts, and the return air temperature controls the PV contacts. When both these contacts are closed, relay R-XX-08 is energized and pilot light PL-XX-03 is turned on. When relays R-XX-03 and R-XX-08 are both energized, the output of mixed air controller TC-XX-01 is received by current-to-pneumatic transducer IP-XX-01 and the economizer outside air, relief air, and return air dampers are modulated to maintain the mixed air temperature controller setpoint.

(4) On a fall in temperature to its setpoint, low temperature protection thermostat TSL-XX-01 opens a set of closed contacts in the supply fan circuit, de-energizing the supply fan. The auxiliary contacts of the supply fan starter de-energize relay R-XX-05, and the contacts of relay R-XX-05 in the return fan starter circuit de-energize the return fan. A set of normally open contacts in low temperature protection thermostat TSL-XX-01 close, energizing relay R-XX-09 and lighting pilot light PL-XX-05. The contacts of relay R-XX-09 energize relay R-XX-12 and relay R-XX-13. One set of the contacts of relay R-XX-12 locks in relays R-XX-12 and R-XX-13, and the normally closed contacts of R-XX-12 de-energize the supply fan. The normally closed contacts of R-XX-13 in the return fan starter circuit de-energize the return fan. To restart the fans after a low temperature shutdown, both low temperature thermostat TSL-XX-01 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-03.

(5) When either smoke detector SMK-XX-01 or smoke detector SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan starter circuit open, de-energizing the supply fan. Its normally open contacts close, energizing relay R-XX-10 and turning on pilot light PL-XX-06. The normally open contacts of R-XX-10 close, energizing relays R-XX-12 and R-XX-13. One set of contacts of relay R-XX-12 locks in relays R-XX-12 and R-XX-13. The other set of contacts of R-XX-12 de-energizes the supply fan, and the contacts of relay R-XX-13 de-energize the return fan. To restart the fans after a smoke alarm shutdown, smoke detectors SMK-XX-01 and/or SMK-XX-02 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-03.

(6) Differential pressure gauge DPI-XX-01 across the filter provides local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-01 turns on filter pilot light PL-XX-04.

(7) Differential pressure gauge DPI-XX-03 across the outside air filter provides local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-03 turns on filter pilot light PL-XX-08.

(8) Temperature controller TC-XX-02, with its temperature transmitter TT-XX-04 in the unit discharge, through the contacts of relay R-XX-06 and current-to-pneumatic transducer IP-XX-02 modulates cooling coil valve VLV-XX-01 to maintain its temperature setpoint. The contacts of relay R-XX-06 are closed during the ventilation delay and occupied modes, allowing control. The contacts are open during the unoccupied mode, the cooling coil valve control signal is interrupted, and the valve remains closed.

(9) A pressure sensing element and transmitter DPT-XX-01 located in the supply duct (the location is determined by field conditions) signals duct static pressure to controller PC-XX-01. Whenever the supply fan runs, the auxiliary contacts of the fan starter energize relay R-XX-07. The output of pressure controller PC-XX-01 is sent, through the contacts of relay R-XX-07, to current-to-pneumatic transducer IP-XX-03. The pneumatic output of the transducer modulates the supply fan inlet vane actuator DA-XX-04 to maintain the pressure controller setpoint. When the fan is de-energized, relay R-XX-07 is de-energized, its contacts open, and the inlet vane dampers remain closed.

(10) When the setpoint of high limit static pressure switch DPS-XX-02 in the supply fan discharge is exceeded, its contacts close, energizing relay R-XX-11 and lighting high-static pilot light PL-XX-07. One set of the contacts of relay R-XX-11 locks in relay R-XX-11, and another set of contacts energizes relays R-XX-12 and R-XX-13. One set of the contacts of relay R-XX-12 locks in relays R-XX-12 and R-XX-13, and the other set of contacts de-energizes the supply fan. The contacts of relay R-XX-13 de-energize the return fan. To restart the fans, manual switch HS-XX-02 must be momentarily depressed and then manual switch HS-XX-03 must be depressed.

(11) Air flow measuring station AFMA-XX-01 and flow transmitter FT-XX-01, located in the supply air duct, and air flow measuring station AFMA-XX-02 and flow transmitter FT-XX-02, located in the return air duct, send flow signals to flow controller FC-XX-01. The output of FC-XX-01, through the contacts of relay R-XX-07, is sent to current-to-pneumatic transducer IP-XX-04. The pneumatic output of IP-XX-04 modulates the return fan inlet vane dampers to maintain the constant differential air volume between the supply and return fans set on controller FC-XX-01. When the fans are de-energized, relay R-XX-07 is de-energized, its contacts open, breaking the control loop, and the return fan inlet vanes remain closed.

(12) Temperature sensing element TE-XX-XX and air flow sensing element FE-XX-XX signal the VAV box controller to modulate reheat coil valve VLV-XX-XX and VAV box damper actuator DA-XX-XX. On a rising space temperature, the VAV box controller first gradually closes VLV-XX-XX and then, after the space temperature passes through a dead band, gradually opens the VAV box beyond minimum air flow position to maximum air flow position to maintain setpoint.

(13) When the occupied contacts of timeclock TC-XX-01 open to end the occupied mode and index the system to the unoccupied mode, relays R-XX-01 and R-XX-02 are de-energized and pilot light PL-XX-01 is turned off. The contacts of relay R-XX-02 open, de-energizing the supply fan and placing the system's night thermostat TSL-XX-02 in control of the supply fan, and, through the supply fan auxiliary contacts and relay R-XX-05, in control of the return fan. On a fall in space temperature to 13 degrees C (55 degrees F), the contacts of TSL-XX-02 close, energizing both fans; on a rise in temperature to 16 degrees C (60 degrees F), the contacts open, de-energizing the fans.

d. Sequence of operation for DDC applications

(1) Ventilation delay mode timing shall start prior to the occupied mode timing. During ventilation delay mode, the dampers shall remain in their normal positions as shown, except when under economizer control. At the time shown, the DDC system shall place the system in the occupied mode. At the expiration of the ventilation delay mode timing period, the DDC system shall place the minimum outside air damper under minimum outside air flow control and shall place the economizer outside air, return air, and relief air dampers under mixed air temperature and economizer control. At the time shown, the DDC system shall place the control system in the unoccupied mode of operation and all dampers shall return to their normal positions as shown.

(2) During occupied and ventilation delay modes the supply fan and return fan shall operate continuously. During unoccupied mode the supply fan and the return fan shall cycle according to the night setback schedule. The fans shall start and stop at the setpoints as shown.

(3) When the supply fan starts, the DDC system shall modulate the inlet vanes from the signal of a static pressure sensing element and transmitter to maintain the setpoint as shown. A high limit static pressure switch in the fan discharge shall stop the supply fan and the return fan and initiate a high static alarm when the static pressure exceeds the setpoint. When the fans are off, the inlet vanes shall be closed.

(4) When the return fan starts, the DDC system shall modulate the return fan inlet vanes from the signals of an air flow measurement station and transmitter in the return air ductwork, in combination with an air flow measurement station and transmitter in the supply air ductwork, to maintain a constant difference between supply air and return air flow rates as shown.

(5) A differential pressure switch across each filter shall initiate a filter alarm when the pressure drop across the filter reaches the setpoint as shown.

(6) A freezestat, located as shown, shall stop the supply and return fans, cause the outside air, return air, and relief air dampers to return to their normal position, and shall initiate a low temperature alarm if the temperature drops below the freezestat's setpoint as shown. The DDC system shall monitor the freezestat through auxiliary contacts and shall indicate an alarm condition when the freezestat trips.

(7) Smoke detectors in the supply air and return air ductwork shall stop the supply fan and the return fan and initiate a smoke alarm if smoke is detected at either location. Restarting the supply fan and the return fan shall require manual reset at the smoke detector.

(8) During occupied and ventilation delay modes, the cooling coil control valve shall be modulated by the DDC system from the signal of a temperature sensing element and transmitter located in the coil discharge air to maintain the setpoint as shown. During unoccupied mode, cooling coil control valve shall remain closed.

(9) Minimum Outside Air Flow Control. When the fans are on, with the control system in the occupied mode, and with the ventilation delay mode off, the minimum outside air damper shall be modulated to maintain the minimum outside air flow at setpoint, as sensed by an air flow measurement station located in the minimum outside air duct.

(10) The DDC system shall accept the signal of an outside air temperature sensing element and transmitter and the signal of a return air temperature sensing element and transmitter. When the return air temperature is above the economizer setpoint, and the outside air temperature is sufficiently below the return air temperature to be effective for cooling, the DDC system shall place the AHU in the economizer mode by modulating the economizer outside air, relief air, and the return air dampers to maintain the mixed air temperature at setpoint. As the economizer outside air and relief air dampers open, the return air damper closes. When the system is not in economizer mode, the economizer outside air and relief air dampers shall remain closed and the return air damper shall remain open.

(11) The control damper of the VAV box shall modulate in response to the signal from a flow sensing element at the discharge or inlet of the VAV box to a microprocessor based VAV box velocity controller. The velocity controller shall control the box damper from the minimum flow position to the full flow position from the signal of a space temperature sensing element located as shown. When the space

temperature decreases, the damper shall gradually close to the minimum flow position to maintain the cooling setpoint as shown. When the space temperature calls for heating after the minimum flow position is reached, control shall then pass through a temperature dead band as shown. When the space temperature has dropped through the dead band, the duct heater coil shall be gradually controlled to maintain the heating setpoint as shown.

23. SINGLE ZONE HVAC CONTROL SYSTEM.

a. Description of the HVAC system. The air handling system consists of a supply fan, economizer dampers, filter, heating coil, and cooling coil. Figures 4-19a through 4-19f show the control system design for this type of air handling system using a SLDC control panel. Figures 4-19g through 4-19j show the control system design for this type of air handling system using DDC controls.

Figure 4-19a. Control system schematic for single zone HVAC system.

Figure 4-19b. Control system ladder diagram for single zone HVAC system.

Figure 4-19c. Control system equipment for single zone HVAC system.

Figure 4-19d. Control panel interior door layout for single zone HVAC system.

Figure 4-19e. Control panel back panel layout for single zone HVAC system.

Figure 4-19f. Control panel terminal block layout for single zone HVAC system.

Figure 4-19g. DDC control system schematic for single zone HVAC system.

Figure 4-19h. DDC control system ladder diagram for single zone HVAC system.

Figure 4-19i. DDC control system equipment for single zone HVAC system.

Figure 4-19j. DDC control system I/O table and data terminal strip layout for single zone HVAC system.

b. General sequence of operation.

(1) Supply fan off. When the fan is off, the cooling coil valve and the outside air and relief air dampers are closed, and the return air damper is open. The heating coil valve remains under space temperature control.

(2) Supply fan operating. When the fan is on, the control dampers and the cooling coil valve are operated as required by the system's operational modes. The control dampers are positioned for full recirculation of air, positioned to introduce minimum outside air, or modulated to maintain space temperature. The cooling coil valve is either closed, or modulated to maintain space temperature.

(3) Control of supply fan. Unless the fan is stopped as the result of a safety shutdown, it is on or off as required by the control system mode of operation.

(4) Safety shutdown of the fan. The control system shuts down the fan if there is a low temperature condition, or if smoke is detected.

(5) Low temperature detection. On a fall in temperature to its setpoint, a low temperature protection thermostat stops the supply fan. To restart the fan, the thermostat and the control panel must be manually reset.

(6) Smoke detection. Duct smoke detectors stop the supply fan whenever either detects the presence of smoke. To restart the fan, the smoke detectors and control panel must be manually reset.

(7) Filter condition. Filter condition is monitored by a pressure gauge and a differential pressure switch. When the rise in pressure drop across the filter reaches the switch setpoint, the switch turns on a pilot light.

(8) Economizer control. When the system does not need full return air recirculation, the dampers are set at minimum position until the economizer controller closes both its PV and DEV contacts. The economizer controller closes its PV contacts when the return air temperature indicates that the building requires cooling rather than heating. The economizer controller closes its DEV contacts when the outside air temperature is sufficiently below the return air temperature to be effective for cooling. When both these contacts close, the dampers are modulated as part of the space temperature control.

(9) Space temperature control. On a rise in space temperature, the heating coil valve is modulated toward closed. On a further rise in temperature, the outside air and relief air dampers are modulated from minimum position toward fully open while the return air damper is modulated toward fully closed. On a still further rise in space temperature, the cooling coil valve is modulated toward open. The reverse occurs on a fall in temperature.

(10) Unoccupied mode of operation. Throughout the unoccupied mode, the outside air and relief air dampers and the cooling coil valve remain closed, and the return air damper remains open. The supply fan is cycled by the system's night thermostat to maintain its low limit space temperature setpoint.

(11) Ventilation delay mode of operation. During the ventilation delay mode, the dampers remain as they were throughout the unoccupied mode, and the supply fan runs continuously. Until the ventilation delay mode ends, return air is circulated, to bring the space to comfort conditions using a minimum of energy. Heating coil and cooling coil valves are under space temperature control.

(12) Occupied mode of operation. The supply fan runs continuously, and the outside air and relief air dampers are at a minimum position or are under space temperature control as previously described.

c. Detailed sequence of operation.

(1) Timeclock CLK-XX-01 has two independent sets of contacts, which between them determine the mode of system operation. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-04 and lighting pilot light PL-XX-02. The normally closed contacts of relay R-XX-04 open, preventing relay R-XX-03 from being energized. The normally

open contacts of relay R-XX-03 prevent any signal from reaching current-to-pneumatic transducer IP-XX-01. Thus, the dampers remain in their normal positions, with outside air and relief air dampers closed and return air damper open.

(2) When the timeclock's occupied contacts close, relays R-XX-01 and R-XX-02 are energized, and pilot light PL-XX-01 is turned on. The contacts of relay R-XX-02 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-05 and, with the contacts of relay R-XX-01, energizes pneumatic valve EP-XX-01, which allows the space temperature controller to control cooling coil valve VLV-XX-02. Temperature setpoint device TSP-XX-01 provides the means for adjusting the setpoint of space temperature controller TC-XX-01.

(3) When the ventilation delay contacts of timeclock CLK-XX-01 open to end the ventilation delay mode of operation, relay R-XX-04 is de-energized and pilot light PL-XX-02 is turned off. The contacts of relay R-XX-04, in series with the now closed but normally open contacts of relays R-XX-01 and R-XX-05, energize relay R-XX-03. The contacts of relay R-XX-03 connect the output signal of high signal selector TY-XX-01 to current-to-pneumatic transducer IP-XX-01. The pneumatic output of transducer IP-XX-01 places the dampers at minimum position unless relay R-XX-06 is energized. Economizer controller EC-XX-01 controls the action of relay R-XX-06. The economizer receives signals from outside air temperature transmitter TT-XX-01 and from return air transmitter TT-XX-02. The difference between the return air temperature and the outside air temperature controls the DEV contacts, and the return air temperature controls the PV contacts. When both these contacts are closed, relay R-XX-06 is energized, and pilot light PL-XX-03 is turned on. The contacts of relay R-XX-06 close, allowing the space temperature controller TC-XX-01 signal to modulate the dampers beyond minimum position.

(4) Space temperature proportional only controller TC-XX-01, with its temperature transmitter TT-XX-03, on a rise in space temperature modulates the heating coil valve toward closed. On a further rise in temperature, it modulates the outside air and relief air dampers from minimum position toward fully open while modulating the return air damper toward closed. On a still further rise in temperature, the cooling coil valve is modulated toward fully open. The reverse occurs on a fall in temperature. Whenever the economizer controller de-energizes relay R-XX-06, the dampers revert to the minimum position set on minimum position switch MPS-XX-01. At the conclusion of the occupied mode, relay R-XX-01 is de-energized and, through its contacts, relay R-XX-03 is de-energized, closing the dampers; pneumatic valve EP-XX-01 is de-energized closing cooling coil valve VLV-XX-02. Heating coil valve VLV-XX-01 is always under the control of temperature controller TC-XX-01.

(5) On a fall in temperature to its setpoint, low temperature protection thermostat TSL-XX-01 opens its set of closed contacts in the supply fan circuit, de-energizing the supply fan. A set of open contacts in low temperature protection thermostat TSL-XX-01 closes, energizing relay R-XX-07 and lighting pilot light PL-XX-05. The contacts of relay R-XX-07 energize relay R-XX-09. One set of the contacts of relay R-XX-09 locks in relay R-XX-09, and the other set de-energizes the supply fan. To restart the fan after shutdown, both low temperature thermostat TSL-XX-01 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-02.

(6) When smoke detector SMK-XX-01 or smoke detector SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan starting circuit open, de-energizing the supply fan. The normally open contacts of the smoke detector(s) close, energizing relay R-XX-08 and lighting smoke pilot light PL-XX-06. The contacts of relay R-XX-08 energize relay R-XX-09. One set of the contacts of

relay R-XX-09 closes to lock in R-XX-09, and the other set of contacts, in the supply fan starter circuit, opens. To restart the fan, the smoke detectors must be manually reset and the HVAC panel must also be reset by depressing momentary switch HS-XX-02.

(7) Differential pressure gauge DPI-XX-01 across the filter provides local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-01 turns on pilot light PL-XX-04.

(8) When the occupied contacts of timeclock TC-XX-01 open to end the occupied mode and index the system to the unoccupied mode, relays R-XX-01 and R-XX-02 are de-energized and pilot light PL-XX-01 is turned off. The contacts of relay R-XX-02 open, de-energizing the supply fan and placing the system's night thermostat TSL-XX-02 in control of the supply fan. On a fall in space temperature to 13 degrees C (55 degrees F), the contacts of TSL-XX-02 close, energizing the fan; on a rise in temperature to 16 degrees C (60 degrees F), the contacts open, de-energizing the fan.

d. Sequence of operation for DDC applications.

(1) Ventilation delay mode timing shall start prior to the occupied mode timing. During ventilation delay mode the dampers shall remain in their normal positions as shown, except when under economizer control. At the time shown, the DDC system shall place the system in the occupied mode. At the expiration of the ventilation delay mode timing period, the DDC system shall place the outside air, return air, and relief air dampers under space temperature and economizer control. At the time shown, the DDC system shall place the control system in the unoccupied mode of operation and the dampers shall return to their normal positions as shown.

(2) During occupied and ventilation delay modes the supply fan shall operate continuously. During unoccupied mode the supply fan shall cycle according to the night setback schedule. The fan shall start and stop at the setpoints as shown.

(3) A differential pressure switch across the filter shall initiate a filter alarm when the pressure drop across the filter exceeds the setpoint as shown.

(4) A freezestat, located as shown, shall stop the supply fan, cause the outside air, return air, and relief air dampers to return to their normal position, and shall initiate a low temperature alarm if the temperature drops below the freezestat's setpoint. Return to the normal mode of operation shall require manual reset at the freezestat. The DDC panel shall monitor the freezestat through auxiliary contacts and shall indicate an alarm condition when the freezestat trips.

(5) Smoke Detectors in the supply air and return air ductwork shall stop the supply fan and initiate a smoke alarm if smoke is detected at either location. Restarting the supply fan shall require manual reset at the smoke detector.

(6) The DDC system shall accept the signal of an outside air temperature sensing element and transmitter and the signal of a return air temperature sensing element and transmitter. The DDC system shall perform switch over between outside air economizer control mode and minimum outside air mode. Until the outside air temperature rises above the setpoint, the DDC system shall hold the system in the minimum outside air mode. When the outside air temperature rises above the setpoint, the DDC system shall place the AHU in the economizer mode or in the minimum outside air mode as determined by a comparison of the outside air and return air temperatures in accordance with the differential temperature setpoints as shown. When the outside air temperature is low with respect to the return air temperature,

the AHU shall be in the economizer mode. When the DDC system places the control system in the minimum outside air mode, the outside air damper shall be open to the minimum outdoor air setting. When the DDC system places the system in the economizer mode, the dampers shall be modulated to admit additional outside air to maintain the space temperature setpoint as shown.

(7) Space temperature control shall be maintained as follows.

(a) During unoccupied mode, the dampers shall remain in their normal positions as shown and the cooling coil valve shall remain closed. The supply fan shall be cycled by the system's night thermostat and the heating coil valve shall be modulated to maintain the space temperature low limit setpoint.

(b) During occupied mode, the supply fan shall run continuously and the heating and cooling coil valves shall be under space temperature control. While the system is in ventilation delay mode, the dampers shall remain in their normal position unless the system is also calling for economizer operation. When the DDC system is in economizer mode, on a rise in space temperature, the DDC system shall first gradually close the heating coil valve. After passing through a deadband, the outside air damper shall be modulated to admit outside air beyond the minimum quantity and after the outside air damper is fully open the cooling coil valve shall be modulated to maintain the space temperature setpoint. When the system is in the minimum outside air mode, the dampers shall remain in the minimum outside air position and the heating and cooling coil valves shall be modulated in sequence to maintain the space temperature setpoint.

24. DUAL-TEMPERATURE COIL SINGLE ZONE HVAC CONTROL SYSTEM.

a. Description of the HVAC system. This air handling system consists of a supply fan, economizer dampers, filter, and dual-temperature coil. Figures 4-20a through 4-20f show the control system design for this type of air handling system using a SLDC control panel. Figures 4-20g through 4-20j show the control system design for this type of air handling system using DDC controls.

Figure 4-20a. Control system schematic for single zone HVAC system with dual-temperature coil.

Figure 4-20b. Control system ladder diagram for single zone HVAC system with dual-temperature coil.

Figure 4-20c. Control system equipment for single zone HVAC system with dual-temperature coil.

Figure 4-20d. Control panel interior door layout for single zone HVAC system with dual-temperature coil.

Figure 4-20e. Control panel back panel layout for single zone HVAC system with dual-temperature coil.

Figure 4-20f. Control panel terminal block layout for single zone HVAC system with dual-temperature coil.

Figure 4-20g. DDC control system schematic for single zone HVAC system with dual-temperature coil.

Figure 4-20h. DDC control system ladder diagram for single zone HVAC system with dual-temperature coil.

Figure 4-20i. DDC control system equipment for single zone HVAC system with dual-temperature coil.

Figure 4-20j. DDC control system I/O table and data terminal strip layout for single zone HVAC system with dual-temperature coil.

b. General sequence of operation.

(1) Supply fan off. When the fan is off, the outside air and relief air dampers are closed and the return air damper is open. The dual-temperature coil valve is under control.

(2) Supply fan operating. When the fan is on, the control dampers and the dual-temperature coil valve are operated as required by the system's operational modes. The control dampers are positioned for full recirculation of air, positioned to introduce minimum outside air, or modulated to maintain space temperature. The dual-temperature coil valve is under control.

(3) Control of supply fan. Unless the fan is stopped as the result of a safety shutdown, it is on or off as required by the control system mode of operation.

(4) Safety shutdown of the fan. The control system shuts down the fan if there is a low temperature condition or if smoke is detected.

(5) Low temperature detection. On a fall in temperature to its setpoint, a low temperature protection thermostat stops the supply fan. To restart the fan, the thermostat and the control panel must be manually reset.

(6) Smoke detection. Duct-smoke detectors stop the supply fan whenever either detects the presence of smoke. To restart the fan, the smoke detectors and control panel must be manually reset.

(7) Filter condition. Filter condition is monitored by a pressure gauge and a differential pressure switch. When the rise in pressure drop across the filter reaches the switch setpoint, the switch turns on a pilot light.

(8) Economizer control. When the control system's mode of operation no longer requires the outside air, return air, and relief air dampers to be in their full recirculation positions, the dampers are positioned to admit outside air for ventilation. When both these contacts close, the dampers are modulated as part of the space temperature control.

(9) Space temperature control. The space temperature controls have different sequences depending on whether hot water or chilled water is being delivered to the unit dual-temperature coil.

(a) Whenever hot water is being supplied to the unit's dual-temperature coil, on a rise in space temperature, the dual-temperature coil valve is modulated toward closed. On a further rise through the temperature deadband, the controls make no changes. Then, on a still further rise in space temperature above the deadband, the outside air and relief air dampers are modulated from the minimum position toward fully open, and the return air damper is simultaneously modulated toward closed.

(b) Whenever chilled water is being supplied to the unit's dual-temperature coil, on a rise in space temperature above the deadband, economizer control permitting, the outside air and relief air dampers are modulated from minimum position toward fully open, and simultaneously the return air damper is modulated toward fully closed and the dual-temperature coil valve is modulated toward open.

(10) Unoccupied mode of operation. During the unoccupied mode throughout the heating season, the supply fan is cycled by the night thermostat to maintain its low limit space temperature setpoint, the outside air and relief air dampers remain closed, and the return air damper remains open. During the unoccupied mode in the cooling season, the unit remains de-energized.

(11) Ventilation delay mode of operation. During the ventilation delay mode, the dampers remain as they were throughout the unoccupied mode, and the supply fan runs continuously. Until the ventilation delay mode ends, return air is circulated, to bring the building to comfort conditions using a minimum of energy.

c. Detailed sequence of operation.

(1) Timeclock CLK-XX-01 has two independent sets of contacts, which between them determine the mode under which the system operates. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-04 and lighting pilot light PL-XX-02. The normally closed contacts of relay R-XX-04 open, preventing relay R-XX-03 from being energized. The normally open contacts of relay R-XX-03 prevent any signal from reaching current-to-pneumatic transducer IP-XX-01. Thus, the dampers remain in their normal positions, with outside air and relief air dampers closed and return air damper open.

(2) When the timeclock's occupied contacts close, relays R-XX-01 and R-XX-02 are energized, and pilot light PL-XX-01 is turned on. The contacts of relay R-XX-02 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-05.

(3) When the ventilation delay contacts of time clock CLK-XX-01 open to end the ventilation delay mode, relay R-XX-04 is de-energized and pilot light PL-XX-02 is turned off. The contacts of relay R-XX-04, in series with the now closed but normally open contacts of relays R-XX-01 and R-XX-05, energize relay R-XX-03. The contacts of relay R-XX-03 close between high signal selector TY-XX-01 and current-to-pneumatic transducer IP-XX-01; this allows the economizer dampers to assume the position set on minimum position switch MPS-XX-01 unless relay R-XX-06 is energized.

(4) Economizer controller EC-XX-01 receives signals from outside air temperature transmitter TT-XX-01 and from return air temperature transmitter TT-XX-02. The difference between the return air temperature and the outside air temperature controls the DEV contacts, and the return air temperature controls the PV contacts. When both these contacts are closed, relay R-XX-06 is energized and pilot light PL-XX-03 is turned on. When relay R-XX-06 is energized, its contacts connect the output of space temperature controller TC-XX-02 to high signal selector TY-XX-01, to modulate the outside air and return air dampers between minimum position and fully open while modulating the return air damper in the opposite direction to maintain the temperature controller setpoint.

(5) Space temperature transmitter TT-XX-03 signals the space temperature to controllers TC-XX-01 and TC-XX-02. Controllers TC-XX-01 and TC-XX-02 are proportional only controllers. Temperature setpoint device TSP-XX-01 provides the means for adjusting the setpoints of space zone temperature controllers, TC-XX-01 and TC-XX-02. On a rise in temperature during the heating season when hot water is being supplied to the dual-temperature coil, space temperature controller TC-XX-02 modulates the dual-temperature coil valve VLV-XX-01 toward closed. On a further rise in space temperature through the temperature deadband, the controller is inactive. On a still further rise in space temperature, economizer controller permitting, controller TC-XX-02 modulates the outside air and relief air dampers from the minimum position set on minimum position switch MPS-XX-01 toward fully open, and simultaneously modulates the return air damper toward closed.

(6) On a fall in temperature to its setpoint, changeover aquastat TS-XX-01 in the dual-temperature water supply energizes electrically actuated pneumatic valve EP-XX-01, which interrupts the TC-XX-02 / IP-XX-02 signal to dual-temperature coil valve VLV-XX-01 and replaces it with the reverse acting TC-XX-01 / IP-XX-03 signal. In addition, TS-XX-01 energizes changeover relay R-XX-10. When relay R-XX-10 is energized, its contacts turn off heating pilot light PL-XX-07 and turn on cooling pilot light PL-XX-08. On a rise in space temperature during the cooling season, temperature controller TC-XX-02, economizer controller permitting, modulates the outside air and relief air dampers AD-XX-01 and AD-XX-03 from minimum position toward fully open and simultaneously modulates the return air damper AD-XX-02 toward fully closed. Controller TC-XX-01, through current-to-pneumatic transducer IP-XX-03, modulates dual-temperature coil valve VLV-XX-01 toward open.

(7) On a fall in temperature to its setpoint, low temperature protection thermostat TSL-XX-01 opens a set of closed contacts in the supply fan circuit, de-energizing the supply fan. A set of open contacts in low temperature protection thermostat TSL-XX-01 closes, energizing relay R-XX-07 and lighting pilot light PL-XX-05. The contacts of relay R-XX-07 energize R-XX-09. One set of the contacts of relay R-XX-09 locks in relay R-XX-09 and the other set de-energizes the supply fan. To restart the fans after a low temperature shutdown both the low temperature thermostat TSL-XX-01 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-02.

(8) When smoke detector SMK-XX-01 or smoke detector SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan starting circuit open, de-energizing the supply fan. The normally open contacts of the smoke detector(s) close, energizing relay R-XX-08 and lighting smoke pilot light PL-XX-06. The contacts of relay R-XX-08 energize relay R-XX-09. One set of the contacts of relay R-XX-09 closes to lock in R-XX-09, and the other set of contacts, in the supply fan starter circuit, opens. To restart the fan, the smoke detectors must be manually reset and the HVAC panel must also be reset by momentarily depressing manual switch HS-XX-02.

(9) Differential pressure gauge DPI-XX-01 across the filter gives local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-01 turns on pilot light PL-XX-04.

(10) When the occupied contacts of time clock CLK-XX-01 open to end the occupied mode and index the system to the unoccupied mode, relays R-XX-01 and R-XX-02 are de-energized and pilot light PL-XX-01 is turned off. The contacts of relay R-XX-02 open, de-energizing the supply fan and placing the system's night thermostat TSL-XX-02 in control of the supply fan. On a fall in space temperature to 13 degrees C (55 degrees F), the contacts of TSL-XX-02 close, energizing the fan; on a rise in temperature to 16 degrees C (60 degrees F), the contacts open, de-energizing the fan.

d. Sequence of operation for DDC applications.

(1) Ventilation delay mode timing shall start prior to the occupied mode timing. During ventilation delay mode the dampers shall remain in their normal positions as shown, except when under economizer control. At the time shown, the DDC system shall place the system in the occupied mode. At the expiration of the ventilation delay mode timing period, the DDC system shall place the outside air, return air, and relief air dampers under space temperature and economizer control. At the time shown, the DDC system shall place the control system in the unoccupied mode of operation and the dampers shall return to their normal positions as shown.

(2) During occupied and ventilation delay modes the supply fan shall operate continuously. During unoccupied mode the supply fan shall cycle according to the night setback schedule. The fan shall start and stop at the setpoints as shown.

(3) A differential pressure switch across the filter shall initiate a filter alarm when the pressure drop across the filter exceeds the setpoint as shown.

(4) A freezestat, located as shown, shall stop the supply fan, cause the outside air, return air, and relief air dampers to return to their normal position, and shall initiate a low temperature alarm if the temperature drops below the freezestat's setpoint. Return to the normal mode of operation shall require manual reset at the freezestat. The DDC panel shall monitor the freezestat through auxiliary contacts and shall indicate an alarm condition when the freezestat trips.

(5) Smoke Detectors in the supply air and return air ductwork shall stop the supply fan and initiate a smoke alarm if smoke is detected at either location. Restarting the supply fan shall require manual reset at the smoke detector.

(6) The DDC system shall accept the signal of an outside air temperature sensing element and transmitter and the signal of a return air temperature sensing element and transmitter. The DDC system shall perform switch over between outside air economizer control mode and minimum outside air mode. Until the outside air temperature rises above the setpoint, the DDC system shall hold the system in the minimum outside air mode. When the outside air temperature rises above the setpoint, the DDC system shall place the AHU in the economizer mode or in the minimum outside air mode as determined by a comparison of the outside air and return air temperatures in accordance with the differential temperature setpoints as shown. When the outside air temperature is low with respect to the return air temperature, the AHU shall be in the economizer mode. When the DDC system places the control system in the minimum outside air mode, the outside air damper shall be open to the minimum outdoor air setting. When the DDC system places the system in the economizer mode, the dampers shall be modulated to admit additional outside air to maintain the space temperature setpoint as shown.

(7) The DDC system shall select the heating and cooling modes based on input from a temperature sensor and transmitter located in the dual-temperature supply. When the dual-temperature supply temperature is above the setpoint, the DDC panel shall operate the dual-temperature coil valve as a heating coil valve in sequence with the outside air, return air, and relief air dampers. When the dual-temperature supply temperature is below the setpoint, the DDC panel shall operate the dual-temperature coil valve as a cooling coil valve in sequence with the outside air, return air, and relief air dampers.

(8) When the DDC system is operating the system in heating mode, space temperature shall be control led as follows.

(a) When the DDC system is in the economizer mode, it shall maintain the setpoint from the signal of a space temperature sensor and transmitter. On a rise in space temperature, the DDC system shall first gradually close the coil valve. After passing through a deadband, the DDC system shall then gradually operate the outside air damper to admit outside air beyond the minimum quantity to maintain the setpoint as shown.

(b) When the DDC system is in the minimum outside air mode, the outside air damper shall be open to the minimum outside air setting. On a rise in space temperature, the DDC system shall gradually close the coil valve to maintain the setpoint as shown.

(9) When the DDC system is operating the system in cooling mode, space temperature shall be controlled as follows.

(a) When the DDC system is in the economizer mode, it shall maintain the setpoint from the signal of a space temperature sensor and transmitter. On a rise in space temperature, the DDC system shall first gradually open the outside air damper to admit outside air beyond the minimum quantity. When the outside air damper is fully open, on a further rise in space temperature, the DDC system shall gradually open the coil valve.

(b) When the DDC system is in the minimum outside air mode, the outside air damper shall be open to the minimum outside air setting. On a rise in space temperature, the DDC system shall gradually open the coil valve to maintain the setpoint.

25. SINGLE ZONE HVAC CONTROL SYSTEM WITH HUMIDITY CONTROL.

a. Description of the HVAC system. This air handling system consists of a supply fan, filter, preheat coil, cooling coil, reheat coil, and humidifier. The system also has a steam-to-water heat exchanger and pump to supply hot water to the preheat and reheat coils. Figures 4-21a through 4-21f show the control system design for this type of air handling system using a SLDC control panel. Figures 4-21g through 4-21j show the control system design for this type of air handling system using DDC controls.

Figure 4-21a. Control system schematic for single zone HVAC system with humidity control.

Figure 4-21b. Control system ladder diagram for single zone HVAC system with humidity control.

Figure 4-21c. Control system equipment for single zone HVAC system with humidity control.

Figure 4-21d. Control panel interior door layout for single zone HVAC system with humidity control.

Figure 4-21e. Control panel back panel layout for single zone HVAC system with humidity control.

Figure 4-21f. Control panel terminal block layout for single zone HVAC system with humidity control.

Figure 4-21g. DDC control system schematic for single zone HVAC system with humidity control.

Figure 4-21h. DDC control system ladder diagram for single zone HVAC system with humidity control.

Figure 4-21i. DDC control system equipment for single zone HVAC system with humidity control.

Figure 4-21j. DDC control system I/O table and data terminal strip layout for single zone HVAC system with humidity control.

b. General sequence of operation.

(1) Supply fan off. When the fan is off, the outside air damper and the cooling coil, humidifier and heat exchanger valves are all closed, and the pump is off. The reheat coil valve remains under space temperature control.

(2) Supply fan operating. When the fan is on, the pump is on, and the outside air damper, heat exchanger valve, preheat coil valve, cooling coil valve, reheat coil valve and humidifier valve are operated as required by the system's operational modes. The outside air damper is either open or closed. The preheat coil and reheat coil valves are under the control of their respective controllers. The cooling coil valve is either closed or modulated to maintain the space temperature and/or humidity.

(3) Control of supply fan. Unless the fan is stopped as the result of a safety shutdown, it is on or off as required by the control system's mode of operation.

(4) Safety shutdown of the fan. The control system shuts down the fan if there is a low temperature condition, or if smoke is detected.

(5) Low temperature detection. On a fall in temperature to its setpoint, a low temperature protection thermostat stops the supply fan. To restart the fan, the thermostat and the control panel must be manually reset.

(6) Smoke detection. Duct smoke detectors stop the supply fan whenever they detect the presence of smoke. To restart the fan, the smoke detectors and control panel must be manually reset.

(7) Filter condition. Filter condition is monitored by a pressure gauge and a differential pressure switch. When the rise in pressure drop across the filter reaches the switch setpoint, the switch turns on a pilot light.

(8) Preheat coil control. The preheat coil valve is modulated to maintain a constant preheat coil discharge temperature.

(9) Space temperature control. The reheat coil valve and cooling coil valve are modulated in sequence to maintain a constant space temperature.

(10) Space humidity control. The humidifier valve and cooling coil valve are modulated in sequence to maintain a constant relative humidity in the space. A high limit humidity control overrides the space control of the humidifier valve when necessary, to prevent the relative humidity in the supply duct from exceeding its high limit setpoint.

(11) Unoccupied mode of operation. Throughout the unoccupied mode, the outside air damper and cooling coil valve remain closed. The supply fan is cycled by the night thermostat to maintain its low limit space temperature setpoint.

(12) Ventilation delay mode of operation. Throughout the ventilation delay mode, the outside air damper remains closed. The reheat coil and cooling coil valves are under the control of the room temperature controller. Return air is circulated, to bring the building to comfort conditions, using a minimum of energy.

(13) Occupied mode of operation. The supply fan runs continuously with the outside air dampers open. The space temperature and humidity are controlled as previously described.

c. Detailed sequence of operation.

(1) Timeclock CLK-XX-01 has two independent sets of contacts, which between them determine the mode under which the system operates. Five minutes before the scheduled beginning of the

occupied mode, the ventilation delay contacts close, energizing relay R-XX-04 and lighting ventilation delay pilot light PL-XX-02. The closed contacts of relay R-XX-04 open, preventing relay R-XX-03 and electrically actuated pneumatic valve EP-XX-01 from being energized. The open contacts of relay R-XX-03 interrupt the signal to IP-XX-03 keeping the humidifier valve closed. When EP-XX-01 is de-energized, the damper remains closed.

(2) When the occupied contacts of timeclock CLK-XX-01 close, relays R-XX-01 and R-XX-02 are energized and pilot light PL-XX-01 is turned on. The contacts of relay R-XX-01 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-05, and since R-XX-01 is already energized it also energizes relay R-XX-06. The contacts of relay R-XX-05 energize the pump starter, and the contacts of relay R-XX-06 place the cooling coil valve under space temperature / humidity control.

(3) When the ventilation delay contacts of timeclock CLK-XX-01 open to end the ventilation delay mode of operation, relay R-XX-04 is de-energized. The normally closed contacts of relay R-XX-04 close, energizing relay R-XX-03 and pneumatic valve EP-XX-01. Pneumatic valve EP-XX-01 opens the outdoor air damper. The contacts of relay R-XX-03 place the humidifier valve under control as described elsewhere.

(4) On a rise in differential pressure to its setpoint, differential pressure switch DPS-XX-01 or DPS-XX-02 lights the filter pilot light PL-XX-03.

(5) On a fall in temperature to its setpoint, the closed contacts of low temperature protection thermostat TSL-XX-01 open, de-energizing the fan; its open contacts close, energizing relay R-XX-07 and lighting low temperature pilot light PL-XX-04. The contacts of relay R-XX-07 energize shutdown relay R-XX-09. One set of the contacts of relay R-XX-09 closes to lock relay R-XX-09 in, and the other set de-energizes the supply fan. To restart the fan, the thermostat and the control panel both must be reset. Momentary switch HS-XX-02 is used to reset the panel.

(6) When either smoke detector SMK-XX-01 or SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan starting circuit open, de-energizing the supply fan. The normally open contacts of the smoke detector(s) close, energizing relay R-XX-08 and lighting smoke pilot light PL-XX-05. The contacts of relay R-XX-08 energize relay R-XX-09. One set of the contacts of relay R-XX-09 close to lock in R-XX-09, and the other set of contacts, in the supply fan starter circuit, opens to de-energize the fan. To restart the fan, the smoke detectors must be manually reset and the HVAC panel must also be reset by depressing momentary switch HS-XX-02.

(7) Whenever the pump runs, the auxiliary contacts of the pump starter energize relay R-XX-10 and light heating pilot light PL-XX-06. The contacts of relay R-XX-10 place heat exchanger valve VLV-XX-05 under control.

(8) Temperature transmitter TT-XX-01 signals the preheat coil discharge temperature to temperature controller TC-XX-01. The output of TC-XX-01 is received by current-to-pneumatic transducer IP-XX-01. The pneumatic output of IP-XX-01 modulates the preheat coil valve VLV-XX-01 to maintain the setpoint of controller TC-XX-01.

(9) Space temperature transmitter TT-XX-02 signals the space temperature to temperature controller TC-XX-02. The output of TC-XX-02 is received by current-to-pneumatic transducer IP-XX-04 and high signal selector TY-XX-01. The pneumatic output of current-to-pneumatic transducer IP-XX-04 modulates the reheat coil valve VLV-XX-03. High signal selector TY-XX-01 passes the higher of the temperature signal and the humidity signal (next paragraph) during the ventilation delay and occupied

modes to current-to-pneumatic transducer IP-XX-02. The pneumatic signal of IP-XX-02 modulates the cooling coil valve VLV-XX-02 to maintain the space temperature or humidity setpoint.

(10) Space humidity transmitter RHT-XX-02 signals the space relative humidity to relative humidity controller RHC-XX-02. The output of relative humidity controller RHC-XX-02 is transmitted to low signal selector RHY-XX-01 and inverter INV-XX-01. Low signal selector RHY-XX-01 also receives a signal from unit discharge high limit humidity controller RHC-XX-01, (must be proportional only) which receives unit discharge relative humidity signals from unit discharge relative humidity transmitter RHT-XX-01. The output of RHY-XX-01, during the occupied mode only, is received by current-to-pneumatic transmitter IP-XX-03, and the pneumatic output of IP-XX-03 modulates humidifier steam valve VLV-XX-04. The signal from controller RHC-XX-02 to inverter INV-XX-01 is reversed and sent to high signal selector TY-XX-01. The signal from space temperature controller TC-XX-02, (previous paragraph) and the signal from space relative humidity controller RHC-XX-02, after inversion are compared, and the higher signal, during the ventilation delay and occupied modes, is sent to current-to-pneumatic transducer IP-XX-02. The pneumatic signal of IP-XX-02 modulates the cooling coil valve VLV-XX-02 to maintain the space temperature or humidity setpoint.

(11) Temperature transmitter TT-XX-03 in the heat exchanger discharge, signals the hot water supply temperature to temperature controller TC-XX-03. Whenever the pump runs, relay R-XX-10 is energized, and, through the contacts of R-XX-10, the output of TC-XX-03, through current-to-pneumatic transducer IP-XX-05, modulates heat exchanger valve VLV-XX-05 to maintain the TC-XX-03 temperature setpoint. When the pump is de-energized, the contacts of relay R-XX-10 open, and the valve closes.

(12) When the occupied contacts of CLK-XX-01 open to end the occupied mode and index the system to the unoccupied mode, relay R-XX-01 is de-energized and pilot light PL-XX-01 is turned off. The contacts of relay R-XX-01 open, de-energizing the supply fan and placing the system's night thermostat TSL-XX-02 in control of the supply fan. On a fall in space temperature to 13 degrees C (55 degrees F), the contacts of TSL-XX-02 close, energizing the fan; on a rise in temperature to 16 degrees C (60 degrees F), the contacts open, de-energizing the fan.

d. Sequence of operation for DDC applications.

(1) Ventilation delay mode timing shall start prior to the occupied mode timing. During ventilation delay mode the outside air damper shall remain closed. At the time shown, the DDC system shall place the system in the occupied mode. At the expiration of the ventilation delay mode timing period, the DDC system shall open the outside air damper. At the time shown, the DDC system shall place the control system in the unoccupied mode of operation and the outside air damper shall close.

(2) During occupied and ventilation delay modes the supply fan shall operate continuously. During unoccupied mode the supply fan shall cycle according to the night setback schedule. The fan shall start and stop at the setpoints as shown.

(3) A differential pressure switch across the filter shall initiate a filter alarm when the pressure drop across the filter exceeds the setpoint as shown.

(4) A freezestat, located as shown, shall stop the supply fan, cause the outside air damper to close, and shall initiate a low temperature alarm if the temperature drops below the freezestat's setpoint. Return to the normal mode of operation shall require manual reset at the freezestat. The DDC panel shall monitor the freezestat through auxiliary contacts and shall indicate an alarm condition when the freezestat trips.

(5) Smoke Detectors in the supply air and return air ductwork shall stop the supply fan and initiate a smoke alarm if smoke is detected at either location. Restarting the supply fan shall require manual reset at the smoke detector.

(6) The DDC system shall modulate the preheat coil control valve from the signal of a temperature sensing element and transmitter in the preheat coil discharge to maintain the setpoint as shown.

(7) During occupied and ventilation delay modes, the DDC system shall compare the signals of a space temperature sensor / transmitter and space relative humidity sensor / transmitter to operate the cooling coil valve. Based on the highest signal received, the DDC system shall modulate the valve to maintain space temperature or space humidity at setpoint. During the unoccupied mode, the cooling coil control valve shall remain closed.

(8) During the occupied mode, the DDC system shall accept the signals from a space relative humidity sensor and a duct relative humidity sensor to control the humidifier valve and the cooling coil valve. The DDC system shall gradually open the cooling coil valve in the event that the space relative humidity continues to rise after the humidifier valve is closed. The DDC system shall gradually operate the humidifier valve from the signal of a space relative humidity sensor / transmitter to maintain relative humidity setpoint. The DDC system shall receive a signal from a relative humidity sensor / transmitter in the ductwork downstream of the humidifier and shall limit the relative humidity at that point to a high limit relative humidity setpoint. During unoccupied and ventilation delay modes, the humidifier valve shall remain closed.

(9) The DDC system shall gradually close the reheat coil valve on a rise in space temperature to maintain the setpoint.

(10) The DDC system shall accept a signal from a temperature sensing element and transmitter in the heating supply line, and shall modulate the hydronic system control valve to maintain the setpoint.

26. SINGLE ZONE HVAC CONTROL SYSTEM WITH DIRECT-EXPANSION (DX) COOLING COIL.

a. Description of the HVAC system. This air handling system consists of a supply fan, economizer dampers, filter, heating coil, and a three stage direct expansion cooling coil. Figures 4-22a through 4-22f show the control system design for this type of air handling system using a SLDC control panel. Figures 4-22g through 4-22j show the control system design for this type of air handling system using DDC controls.

Figure 4-22a. Control system schematic for single zone HVAC system with DX coil.

Figure 4-22b. Control system ladder diagram for single zone HVAC system with DX coil.

Figure 4-22c. Control system equipment for single zone HVAC system with DX coil.

Figure 4-22d. Control panel interior door layout for single zone HVAC system with DX coil.

Figure 4-22e. Control panel back panel layout for single zone HVAC system with DX coil.

Figure 4-22f. Control panel terminal block layout for single zone HVAC system with DX coil.

Figure 4-22g. DDC control system schematic for single zone HVAC system with DX coil.

Figure 4-22h. DDC control system ladder diagram for single zone HVAC system with DX coil.

Figure 4-22i. DDC control system equipment for single zone HVAC system with DX coil.

Figure 4-22j. DDC control system I/O table and data terminal strip layout for single zone HVAC system with DX coil.

b. General sequence of operation.

(1) Supply fan off. When the fan is off, the outside air and relief air dampers are closed and the return air damper is open. The heating coil valve is under control.

(2) Supply fan operating. When the fan is on, the control dampers are either positioned for full recirculation of air, positioned to introduce minimum outside air, or modulated to maintain space temperature. The cooling is either de-energized or cycled in stages to maintain space temperature.

(3) Control of supply fan. Unless the fan is stopped as the result of a safety shutdown, it is on or off as required by the control system's mode of operation.

(4) Safety shutdown of the fan. The control system shuts down the fan if there is a low temperature condition, or if smoke is detected.

(5) Low temperature detection. On a fall in temperature to its setpoint, a low temperature protection thermostat stops the supply fan. To restart the fan, the thermostat and the control panel must be manually reset.

(6) Smoke detection. Duct smoke detectors stop the supply fan whenever they detect the presence of smoke. To restart the fan, the smoke detectors and control panel must be manually reset.

(7) Filter condition. Filter condition is monitored by a pressure gauge and a differential pressure switch. When the rise in pressure drop across the filter reaches the switch setpoint, the switch turns on a pilot light.

(8) Economizer control. When the control system's mode of operation no longer requires the outside air, return air, and relief air dampers to be in their full recirculating positions, the dampers are positioned to admit outside air for ventilation. The amount of ventilation air then remains at minimum until the economizer controller closes both its PV and DEV contacts. The economizer controller closes its PV contacts when the return air temperature indicates that the building requires cooling rather than heating. The economizer controller closes its DEV contacts when the outside air temperature is sufficiently below the return air temperature to be effective for cooling. When both these contacts close, the dampers are modulated as part of the space temperature control.

(9) Space temperature control. On a rise in space temperature, the heating coil valve is modulated toward closed. On a further space temperature rise, economizer control permitting, the outside air and relief air dampers are modulated between minimum position toward fully open, and simultaneously the return air damper is modulated toward fully closed to maintain space temperature. On a still further rise in temperature, the stages of cooling are cycled to maintain the space temperature.

(10) Unoccupied mode of operation. Throughout the unoccupied mode, the outside air and relief air dampers remain closed, and the return air damper remains open. The heating coil valve remains under space temperature control. The cooling stages are de-energized. The supply fan is cycled by the system's night thermostat to maintain its low limit space temperature setpoint.

(11) Ventilation delay mode of operation. During the ventilation delay mode, the dampers remain as they were throughout the unoccupied mode, and the supply fan runs continuously. The cooling system is enabled. Until the ventilation delay mode ends, return air is circulated, to bring the building to comfort conditions, using a minimum of energy.

(12) Occupied mode of operation. The supply fan runs continuously, and the outside air and relief air dampers are at minimum position or are under space temperature control as previously described.

c. Detailed sequence of operation.

(1) Timeclock CLK-XX-01 has two independent sets of contacts, which between them determine the mode under which the system operates. Five minutes before the scheduled beginning of the occupied mode, the ventilation delay contacts close, energizing relay R-XX-04 and lighting pilot light PL-XX-02. The normally closed contacts of relay R-XX-04 open, preventing relay R-XX-03 from being energized. The normally open contacts of relay R-XX-03 prevent any signal from reaching electric damper actuators DA-XX-01, DA-XX-02, and DA-XX-03. Thus, the dampers remain in their normal positions, with outside air and relief air dampers closed and return air damper open.

(2) When the timeclock's occupied contacts close, relays R-XX-01 and R-XX-02 are energized, and occupied pilot light PL-XX-01 is turned on. The contacts of relay R-XX-02 energize the supply fan. The auxiliary contacts of the supply fan starter energize relay R-XX-05 and, with the contacts of relay R-XX-01, energize relay R-XX-06, which places the space temperature controller TC-XX-01 in control of cooling sequencer SQCR-XX-01.

(3) When the ventilation delay contacts of timeclock CLK-XX-01 open to end the ventilation delay mode, relay R-XX-04 is de-energized and pilot light PL-XX-02 is turned off. The contacts of relay R-XX-04 energize relay R-XX-03. The contacts of relay R-XX-03 close between high signal selector TY-XX-01 and the electric damper actuators. This allows the economizer dampers to assume the position set on minimum position switch MPS-XX-01 unless relay R-XX-07 is energized.

(4) Economizer controller EC-XX-01 receives signals from outside air temperature transmitter TT-XX-01 and from return air temperature transmitter TT-XX-02. The difference between the return air temperature and the outside air temperature controls the DEV contacts, and the return air temperature controls the PV contacts. When both these contacts are closed, relay R-XX-07 is energized and pilot light PL-XX-03 is turned on. When relay R-XX-07 is energized, its contacts connect the output of space temperature controller TC-XX-01 to high signal selector TY-XX-01, to modulate the outside air and return air dampers between minimum position and fully open while modulating the return air damper in the opposite direction to maintain the temperature controller setpoint.

(5) Space temperature transmitter TT-XX-03 signals the space temperature to proportional only space temperature controller TC-XX-01. The TC-XX-01 output through loop drivers LD-XX-01, LD-XX-02, and LD-XX-03 controls the cooling sequencer, the economizer dampers, and the heating coil valve respectively. On a rise in space temperature, controller TC-XX-01 through loop driver LD-XX-03 modulates heating coil valve VLV-XX-01 closed. On a further temperature rise, if the economizer

controller permits, the controller, through loop driver LD-XX-02, modulates the outside air and relief air dampers from minimum position toward fully open and simultaneously modulates the return air damper toward fully closed. On a still further rise, the controller, through loop driver LD-XX-01 and sequencer SQCR-XX-01, successively energizes the stages of cooling. The reverse occurs on a fall in temperature.

(6) On a fall in temperature to its setpoint, low temperature protection thermostat TSL-XX-01 opens a set of closed contacts in the supply fan circuit, de-energizing the supply fan. A set of open contacts in low temperature protection thermostat TSL-XX-01 closes, energizing relay R-XX-08 and lighting low temperature pilot light PL-XX-05. The contacts of R-XX-08 energize relay R-XX-10. One set of the contacts of relay R-XX-10 locks in relay R-XX-10, and the other set de-energizes the supply fan. To restart the fans after a low temperature shutdown both the low temperature thermostat TSL-XX-01 and the control panel must be manually reset. The control panel is reset by momentarily depressing manual switch HS-XX-02.

(7) When smoke detector SMK-XX-01 or smoke detector SMK-XX-02 detects the presence of smoke, its normally closed contacts in the supply fan starting circuit open, de-energizing the supply fan. The normally open contacts of the smoke detector(s) close, energizing relay R-XX-09 and lighting smoke pilot light PL-XX-06. The contacts of relay R-XX-09 energize relay R-XX-10. One set of the contacts of relay R-XX-10 closes to lock in R-XX-10, and the other set of contacts, in the supply fan starter circuit, opens. To restart the fan, the smoke detectors must be manually reset and the HVAC panel must also be reset by depressing momentary switch HS-XX-02.

(8) Differential pressure gauge DPI-XX-01 across the filter provides local indication of filter loading. On a rise in pressure drop across the filter to its setpoint, differential pressure switch DPS-XX-01 turns on pilot light PL-XX-04.

(9) When the occupied contacts of time clock CLK-XX-01 open to end the occupied mode and index the system to the unoccupied mode, relays R-XX-01 and R-XX-02 are de-energized and pilot light PL-XX-01 is turned off. The contacts of relay R-XX-02 open, de-energizing the supply fan and placing the system's night thermostat TSL-XX-02 in control of the supply fan. On a fall in space temperature to 13 degrees C (55 degrees F), the contacts of TSL-XX-02 close, energizing the fan; on a rise in temperature to 16 degrees C (60 degrees F), the contacts open, de-energizing the fan.

d. Sequence of operation for DDC applications.

(1) Ventilation delay mode timing shall start prior to the occupied mode timing. During ventilation delay mode the dampers shall remain in their normal positions as shown, except when under economizer control. At the time shown, the DDC system shall place the system in the occupied mode. At the expiration of the ventilation delay mode timing period, the DDC system shall place the outside air, return air, and relief air dampers under space temperature and economizer control. At the time shown, the DDC system shall place the control system in the unoccupied mode of operation and the dampers shall return to their normal positions as shown.

(2) During occupied and ventilation delay modes the supply fan shall operate continuously. During unoccupied mode the supply fan shall cycle according to the night setback schedule. The fan shall start and stop at the setpoints as shown.

(3) A differential pressure switch across the filter shall initiate a filter alarm when the pressure drop across the filter exceeds the setpoint as shown.

(4) A freezestat, located as shown, shall stop the supply fan, cause the outside air, return air, and relief air dampers to return to their normal position, and shall initiate a low temperature alarm if the temperature drops below the freezestat's setpoint. Return to the normal mode of operation shall require manual reset at the freezestat. The DDC panel shall monitor the freezestat through auxiliary contacts and shall indicate an alarm condition when the freezestat trips.

(5) Smoke Detectors in the supply air and return air ductwork shall stop the supply fan and initiate a smoke alarm if smoke is detected at either location. Restarting the supply fan shall require manual reset at the smoke detector.

(6) The DDC system shall accept the signal of an outside air temperature sensing element and transmitter and the signal of a return air temperature sensing element and transmitter. The DDC system shall perform switch over between outside air economizer control mode and minimum outside air mode. Until the outside air temperature rises above the setpoint, the DDC system shall hold the system in the minimum outside air mode. When the outside air temperature rises above the setpoint, the DDC system shall place the AHU in the economizer mode or in the minimum outside air mode as determined by a comparison of the outside air and return air temperatures in accordance with the differential temperature setpoints as shown. When the outside air temperature is low with respect to the return air temperature, the AHU shall be in the economizer mode. When the DDC system places the control system in the minimum outside air mode, the outside air damper shall be open to the minimum outdoor air setting. When the DDC system places the system in the economizer mode, the dampers shall be modulated to admit additional outside air to maintain the space temperature setpoint as shown.

(7) Space temperature control shall be maintained as follows.

(a) During unoccupied mode, the dampers shall remain in their normal positions as shown and the DX condensing unit shall remain off. The supply fan shall be cycled by the system’s night thermostat and the heating coil valve shall be modulated to maintain the space temperature low limit setpoint.

(b) During occupied mode, the supply fan shall run continuously and the heating coil and the DX cooling coil shall be under space temperature control. While the system is in ventilation delay mode, the dampers shall remain in their normal position unless the system is also calling for economizer operation. When the DDC system is in economizer mode, on a rise in space temperature, the DDC system shall first gradually close the heating coil valve. After passing through a deadband, the outside air damper shall be modulated to admit outside air beyond the minimum quantity and after the outside air damper is fully open, the DDC system shall operate the stages of cooling in sequence to maintain the space temperature setpoint. When the system is in the minimum outside air mode, the dampers shall remain in the minimum outside air position. On a rise in space temperature, the DDC system shall first gradually close the heating coil valve. After passing through a deadband, the DDC system shall operate the stages of cooling in sequence.